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PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

GENERAL MEETING, HELD IN BELGIUM, AUGUST 18TH, 1873.

THE summer meeting of the Iron and Steel Institute was held at Liége, and commenced on Monday, August 18th. On that day, at 12·30, the members arrived at the Guillemins Station, which had been taken possession of long before that hour by a crowd of Belgian ironmasters and engineers. The company of the fire brigade and three bands of music were at the station. The members, who were greeted with loud acclamations, were received on the platform by M. Trasenster and M. J. d'Andrimont, and were by them conducted to the numerous private carriages which had been placed at their disposal. Belgian and English flags were displayed all along the route from the station to the Place du Theatre, and the city altogether was *en fete*. The reception by the communal administration, in the first instance fixed at one o'clock, was postponed to two o'clock, and at that time the members of the Iron and Steel Institute were received at the Hotel de Ville by M. Piercot, the Burgomaster, who was supported by Messrs. Bourdon, Gillon, and Verdin, Aldermen; by Messrs. Renier Malherbe, Pirotte, Modave, Ziane, and Graindorge, Communal Councillors. M. Piercot, in very warm terms, thanked the members of the Iron and Steel Institute for the honour they had done the town of Liége in selecting it as the place of their first continental meeting. "You will find with us," said the burgomaster, "the liberty and the free institutions which you enjoy in England; you will find an industrious and intelligent population, accustomed to express their ideas frankly, and to show their preferences without restraint. This population which, with one consent, has to-day put on its holiday

attire, will welcome you, because they admire you as the promoters of great and generous ideas, and the introducers of processes destined to render immense services to industry. You have understood that labour must no longer be trammelled, and that manufacturers must tend to one and the same goal, and move to progress by each informing the other of the useful reforms to be made. You will visit our works, our coalmines, our establishments, and you will see that we have set to work processes, the illustrious inventors of which are now amongst us." In conclusion, the burgomaster, in the name of the city of Liége, welcomed the members of the Iron and Steel Institute. Mr. I. L. Bell, chairman of the Institute, replied to M. Piercot, thanking the communal administration warmly for the kind remarks that had been made by the burgomaster, and for the grand reception the members of the Institute had met with at Liége. After this the "wine of honour" was given out, and Belgians and Englishmen fraternised by drinking to the Iron and Steel Institute.

Sitting at the Salle Académique.—At 2·30 p.m., the members of the Iron and Steel Institute, and of the Belgian Reception Committee, met in the Lecture Hall of the University, which was tastefully decorated with trophies—Belgian and English flags.

Mr. I. Lowthian Bell, the President of the Institute, who had taken the chair, read, in French, an address, of which the following is a translation:—

Gentlemen,—At the period of the establishment of the Iron and Steel Institute, probably the most sanguine among us limited our expectations to seeing it occupy a position of usefulness among the iron and steel manufacturers of Great Britain. Art and science, however, recognise no political or geographical boundary, and our rules were, very properly and designedly, so framed as to admit to the rights of membership any one interested in our proceedings, to whatever nation or continent he might belong. Among the proofs of the success we have, as an Institute, achieved, certainly not the least in importance has been the applications for admission from gentlemen in all parts of the world, the list embracing not only those who have distinguished themselves as successful manufacturers, but also the names of some of the greatest metallurgical philosophers of the day.

I trust I am correctly interpreting the sentiments of our hosts, at whose invitation we are now assembled on a foreign soil, when I read their graceful offer of hospitality as a mark of sympathy with the object we have in view, and as evidence of an intention on their part to assist us in its pursuit.

There is something peculiarly appropriate in Belgium being the first continental state which has honoured the Iron and Steel Institute with a request to visit and examine its industrial undertakings. Politically and socially there have existed for very many years the most cordial relations between the inhabitants of this country and those of our own. The sovereigns of the two kingdoms are known to entertain for each other sentiments of the warmest friendship. We hear of annual meetings of friendly rivalry between the Riflemen of Belgium and Great Britain, and we, who are engaged in pursuits of a purely peaceful nature, may also be permitted to hope, that our visit may assist in strengthening those amicable relations, the rupture of which between nations is not unfrequently a signal of misery and desolation. We come, it is true, to meet those whom we regard, and by whom we are regarded, as formidable but honourable rivals; but we unite with our rivalry a willingness on each side to instruct the other in the use of the weapons by which victory has to be won.

Apart, however, from these considerations of a general character, Belgium possesses other claims which render a visit to it full of the deepest interest to those who, like ourselves, are engaged in manufacturing operations; for it would be impossible to find a land in which industrial science has been more fully studied, or more intelligently applied, than it has been by the ancestors of our present hosts and by themselves. As a consequence of this wise course of national action, we have a territory covered with a dense population, able, by its energetic labour not only to supply its own wants, but also to export largely of the results of that labour, for the use of other countries less favoured by Nature, or less advanced in the art of converting natural products for the use of mankind.

It would be quite foreign to the purposes of this meeting were any time devoted even to the mere enumeration of the various imports or exports, or of the manufactures themselves, indicative of the high trading position of the Belgian people. That which alone interests us, and to which I alone feel myself justified in

alluding, are those branches allied with the production of iron, and even this must necessarily be done in very general terms.

As you well know, the foundation of Belgium's capability as an iron making country lies in her coalfields, in which, however, the mineral is found under such conditions, in respect to depth and the nature of the beds, as to have taxed to the uttermost the ingenuity of her mining engineers to furnish this indispensable element of commercial greatness. In spite, however, of any natural obstacles which have to be surmounted in working the collieries of this country, the system adopted is such as to enable the Belgian coalowners, not only to meet the demands of home consumption, but also to furnish to other nations no inconsiderable quantities of the produce of their mines. This, during the past year, amounted to between five and six millions of tons, which is about one-third the quantity exported from Great Britain during the same period, the entire produce of the latter being about 123 millions of tons against something like 14 millions, which, I understand, was the output of Belgium.

Although the coal formation proper of Belgium, like that of Northumberland and Durham, is destitute of workable beds of ironstone, the adjacent schistose rocks and limestones are fairly rich in ores of the hematite class. A portion of these is exported, not however from any actual superabundance, because four or five times as large a quantity is brought into the country as that supplied by it to foreign nations. In the year 1872, the weight so imported amounted to nearly 800,000 tons, chiefly obtained from France and Germany.

With the above-mentioned advantages of coal and ores of iron, in the hands of an enterprising people, it is only natural that early attention should have been paid to the establishment of ironworks in Belgium.

Prior, however, to the year 1828, the pig iron made in this country was almost exclusively smelted with charcoal, and, as a matter of commercial importance, when estimated by its extent, so long as the forest and not the mine, is the source of the furnace fuel no nation can long occupy a very prominent position in the iron trade of the world. In all Belgium there were at that time, I believe, not above half-a-dozen coke furnaces, and I trust I may be pardoned if I remind a meeting held in Liége, that

to a fellow countryman of our own, John Cockerill, is due the honour of building the first coke blast furnace in this country. This was the origin of the important establishment at Seraing, which, under the subsequent highly intelligent supervision of M. Gustave Pastor, and under the present able management of M. Sadoine, has become one of the famous works of the present age.

More than thirty years ago, the Stockton and Darlington railway was opened for public traffic, and the powers of the locomotive had been tested, but apparently not sufficiently so to satisfy the minds of many in our own land, that this new system of transport was destined to revolutionize the industry of the world. In proof of this, instances were then not wanting of powerful individuals, succeeding by their influence, in debarring whole communities from the benefits of railway communication. More enlightened views directed the councils of the Belgian authorities, for they appear to have been early impressed with the national importance of connecting their great centres of commerce with each other, and of facilitating the means of conveying the produce of their mineral fields to the various points where it was to be consumed. Belgium, guided by this policy, was the first continental power which sought to introduce a general system of railways throughout its territory, and the late King Leopold, a name held in high esteem by all Englishmen, honoured with marked distinction and favour, George Stephenson, under whose direction the first lines in this kingdom were constructed.

But the rulers who preside over the destinies of this country have wisely seen, that in order to turn to the best account the elements of national prosperity placed at their disposal, those engaged in the mines and manufactures must be suitably educated for the proper discharge of their various duties. For this purpose, throughout the country, we find located schools of the highest order of excellence for the teaching of practical science. Among these it may be permitted to mention :—

The Ecole des Mines, at Liége.

„ Ecole des Ponts et Chaussées, at Ghent.

„ Ecole des Arts et Manufactures et des Mines, at Louvain.

„ Ecole des Mines, at Mons.

„ Ecole des Mineurs, at Charleroi.

The last one named in this list, it should be especially remarked, is devoted to the education of men in the position of our underviewers and foremen of departments.

Besides these, there are numerous others for communicating instruction in advanced industrial science, both theoretical and practical, and, next year, will be added to the University of Brussels, Chairs for teaching the usual branches of learning afforded in mining schools. The existence of such establishments as those to which I have alluded, will account for the fact of there being found in the Belgian ironworks, so many scientifically educated managers and directors, and that the manufacturing operations under their superintendence, so far as my observation enables me to judge, are conducted in a manner dictated by sound principles of economy, as the same are understood at the present day.

Attached to these seats of learning, there have been, and are, teachers of unquestionable capacity. The name of M. Adolphe Lesoinne, Professor of Metallurgy, at the University in this town, is associated with the most indefatigable labour to render his course of lectures of the highest practical utility to the students; and my personal intercourse with M. Krans, of Louvain, an old student of Liége, has led me to infer that the Professors, generally, entertain a high sense of the importance of their mission, by the care with which they themselves study the constant changes introduced into the processes they have undertaken to explain. The list of eminent men I could name is a long one, but I must limit myself to that of the worthy president of the Committee of Reception, M. Trasenster.

I have more than once had occasion to observe that hitherto a systematic study of the principles upon which our processes are founded, has received more attention at the hands of scientific investigators on the Continent than in our own country. In illustration of this, I may mention that so early as 1844, M. Valerius, a native of Belgium, published his work on the manufacture of iron, which was followed seven years afterwards by a second, of great excellence, on that of pig iron, chiefly in relation to the smelting establishments in this immediate neighbourhood; and for the last sixteen years there has appeared at Liége the *Revue Universelle des Mines et de la Metallurgie,* a periodical which enjoys as high a reputation as an older one of the same character, I mean the *Annales des Mines* of Paris.

Assembled as we now are, away from the home of the Institute, at one of the localities, and within a few hours' journey of others, in the three great ironmaking States of Continental Europe, viz., Belgium, France, and Germany, it may be interesting to consider, very briefly, of course, some of the peculiar circumstances affecting the production of this metal as compared with those of our own country.

The history of the expansion of the iron trade during the last twenty-five or thirty years, indicates with remarkable clearness the nature of those social changes which have followed the introduction of improved modes of transit and of extended international communication. A community of a purely pastoral and agricultural character is more or less shut out from the world, when the physical difficulties attending the export of its produce are such as to check its commerce with the rest of mankind. The life of its inhabitants is necessarily of the simplest kind, and the money value of the fruits of their labour and of the labour itself, will be found very small, when compared with that of a people occupying a more fortunate position.

When manufacturing industry is introduced to a limited extent into such a society as the one I have just named, the artisan is more or less affected by the prevailing condition of the surrounding population—living is cheap, and wages are low. At a time (1870) when animal food was selling in England at 7d. to 8d. per lb., its cost at Fullonica, in Italy, I found to be only 5½d.; but the field labourers received only 1s. to 1s. 2d. per day, blast furnace keepers a little above 4s., and slagmen 2s. 10d. At Irun, in Spain, the miners in the iron mines were content to work for 2s.; and at Bilbao, where butcher-meat (1872) was sold at 4½d. per lb., furnace keepers had 4s. 6d., best blacksmiths 3s. 6d. per day, and puddlers 6s. per ton, rates which were less than two-thirds of those current in England at the same time. It is unnecessary to multiply instances all pointing to the same result, otherwise figures might be given showing, generally speaking, cheap food and low earnings by the men in the ironworks of Norway, Sweden, and Austria.

It might, at first sight, seem immaterial what a man's wages were, provided the cost of the necessaries of life corresponded with the rate of his pay. It is, however, a remarkable fact that, as a rule, however low priced provisions may be in these cheap countries, labour is paid for on such a scale as to compel the greater portion of the working population to subsist on very miserable

fare. Thus, the ordinary diet of the countryman in the south of Spain, with his fifteen pence per day, consists of *gaspacho*, to furnish which he boils in water one kilo of bread and one ounce of olive oil, and this serves for all his meals for one day. Very few of the workmen of the superior class partake habitually of animal food, and, as a consequence, we find inability for any great physical exertion, which necessitates the employment of an increased number of hands, compared with that required under a different condition of things. I met with a notable instance of this at a blast furnace near Malaga, making about 35 tons of iron per week, at which four men were constantly engaged at the hearth, whose united wages amounted to only 6s. 10d. per day, or an average of 1s. 8½d. each. In such cases no thought is bestowed on economizing labour, which partly accounts for the presence of these four men, and for the seven who, I ascertained, were required for filling the furnace in question. Thus we have, for the causes just mentioned, about twice as many workmen engaged in turning out about as much iron in one week as some of our English furnaces are able to do in twelve hours.

Great Britain presents the very antithesis to a community living under the circumstances I have named. Its mineral wealth led to the organisation of manufacturing undertakings, in which coal or iron ore entered largely, and there was, and is maintained within its dominions, a population far in excess of the food-producing powers of its soil. To supply this deficiency, recourse had to be made to foreign nations, whose means and position enabled them to afford the necessary assistance. It is true, for many years an artificial barrier was raised against the unrestricted importation of the necessaries of life, on the ground that the owners of land, farmers, and agricultural labourers, would be overwhelmed in common ruin by what was designated as unfair competition. The experience, however, of thirty years of free trade, has proved that every section of society in the British Isles, whether territorial, agricultural, or industrial, has largely profitted by the change in national policy.

With all this help from without, human food is unquestionably dearer with us than in any other part of the world, but, on the other hand, wages are such as to enable our labouring class to live in a manner never dreamt of by an inhabitant of many districts where living is within reach upon much easier terms.

With regard to the three nations whose iron-making capability I propose briefly comparing with that of Great Britain, we should probably not be wide of the mark in supposing that fifty years ago they resembled pretty closely Spain and Italy at the present day, *i.e.*, agriculture was practically the only pursuit of their inhabitants, and the produce of the husbandman's labour was disposed of at very low prices.

The formation of railways, and the extension of steam navigation, have enabled the farmers of Belgium, France, and Germany, to forward their crops at a small expense to more distant markets than was within the power of their predecessors. These same railways have also afforded facilities for rendering available the natural resources, mineral, and otherwise, of these respective countries, and hence there has rapidly sprung into existence a vast number of industrial establishments, metallurgical as well as others.

These two sources of outlet have sensibly affected the value of the fruits of the soil, and, as an example, I may quote one instance of a German province in which, compared with 25 years ago, butcher-meat and butter show an increase in the one case of 50 to 80 per cent., and in the other of nearly 85 per cent.

Along with this change in the cost of living, wages had also risen at the period of my enquiry (1867), so that, speaking generally, it may now be assumed the price of food and wages, in the three countries under consideration, occupy an intermediate place between Great Britain and those where the population are almost exclusively engaged in tilling the land.

To show upon what foundation this opinion is based, I have extracted from my notes of a journey performed in 1867, the different figures of rates of wages given me at different works I visited. In France, where butcher-meat was charged about 7d. per lb.—

		s. d.	
Coal Hewers were paid—2/6¾, 2/9½, 3/2½, 3/7¼, 3/9½, 4/0, 4/0	...Average	3/5	per day.
Coal Putters—1/7, 2/0, 2/0, 2/9½	„	2/1	„
Labourers in Ironworks—2/2½, 2/2¼, 2/5, 2/5, 2/10	„	2/5	„
Coke Burners—2/5, 3/2½	„	2/9¾	„
Masons—3/2½, 3/2½, 3/7½	„	3/4	„
Joiners—	„	3/2½	„

		s. d.	
Blast Furnace Keepers—3/2½, 3/3, 4/0	...Average	3/6	per day.
„ Assistant—2/4½, 2/9½	... „	2/7	„
„ Slagmen—	... „	2/9½	„
Puddling iron per ton—5/10, 5/10, 6/2¾, 6/4, 6/9½, 7/2½	... „	6/4¾	per ton.

On the Rhine the price of animal food was given me as 7¼d. per lb.—

Coal Hewers received—3/0, 4/0 ...	...Average	3/6	per day.
Labourers in Ironworks—1/6, 2/0	... „	1/9	„
Coke Burners—	... „	3/0	„
Blast Furnace Keepers—3/0, 3/6, 4/0	... „	3/6	„
„ Assistant—2/6, 2/10, 3/0	... „	2/9	„
„ Slagmen—2/0, 2/0, 2/3	... „	2/1	„
Puddling iron per ton—4/9¾, 5/5, 5/5, 5/7, 5/8	... „	5/5	per ton.
Head Rollers—	... „	6/0	per day.

In Belgium, butcher-meat could be had for 7½d. per lb.—

Coal Hewers were paid—3/2½, 4/0, 4/9½	...Average	4/0	per day.
Blast Furnace Keepers—	... „	2/4¾	„
„ Assistant—	... „	2/1	„
„ Slagmen—	... „	2/1	„
Puddling iron per ton—4/0, 4/9½ ...	... „	4/4¾	per ton.
Head Roller—4/0, 4/9½	... „	4/4¾	per day.

In the County of Durham, where animal food, in 1867, cost 7d. to 8d. per lb.—

Coal Hewers earned from 4/1½ to 5/6	...Average	4/9¾	per day.
Putters—2/0 to 3/0	... „	2/6	„
Labourers in Ironworks	... „	2/10	„
Coke Burners—	... „	4/8	„
Masons—		4/6	„
Joiners—		3/6	„
Blast Furnace Keepers—	... „	6/3	„
„ Slagmen—	... „	4/0	„
Puddling iron—	... „	8/0	per ton.

It is only proper to observe that any attempt to institute a rigid comparison between the expense of manufacturing iron in the different countries named, based on the above figures as factors, would only lead to fallacious results. This is due to natural

differences in the raw materials of coal and ore, and to the fact that in Great Britain dearer labour has forced upon the manufacturer more complete arrangements for its economy. Messieurs Gruner and Lan, in their very comprehensive and able work on the state of the iron manufacture of England, written in 1862, mention, in regard to wages, that labour, which in France costs one franc, commanded one shilling with us. Without knowing their opinion, I arrived at the same conclusion as regards France, and the same difference appears to obtain in Belgium and Germany when compared with the rates then prevailing in Great Britain.

I shall not venture to express any views on the future of the labour market in either the British or Continental iron trade. As you are all aware, within the last year or eighteen months, under the influence of an unusual demand for every species of industrial product, wages have experienced, generally, the most extraordinary and unlooked for changes. In the ironworks with us it may be taken that the rates of to-day are 50 per cent. above those of 1871. So far, however, as I have been able to ascertain, the increase which has taken place on the Continent is not above one-half of that which has been conceded by the English and Scotch ironmasters.

The class which is directly benefited by an augmentation in the value of the product of the soil is, of course, the agriculturist, and it might be thought that so far as the exportation of provisions tends to raise the cost of living in the exporting country, the manufacturing interest derives the reverse of any advantage from the change. Against this, however, we have the admitted fact that concurrently all branches of industry in Western Europe have progressed with strides unknown in the world's previous history. As regards iron this is strikingly true, and in spite of any increased cost of production due to higher wages, improvements, in machinery and in some of the processes themselves, have, until very recently, enabled the ironmaster to deliver the metal to the consumer on as favourable terms as formerly. Leaving the present abnormal condition of industrial affairs on one side, and confining ourselves to the relative state of the manufacture of iron in Great Britain and on the Continent, as it existed two years ago, and for some time previously, the obvious question arises, as to what the supremacy of the former is due .in the matter of quantity produced. In the actual cost of a given amount of labour we stand in an

admittedly less favourable position than our colleagues in Belgium, France, or Germany. Do we possess greater natural advantages in the possession of raw materials than they, is the question to which I propose shortly directing your attention.

In respect to ore, many difficulties intrude themselves in the enquiry, due to great differences which exist in the facilities attending the extraction of the mineral and its conveyance to the furnaces in different localities of the same State. As an example, in our own country the cost of ore on a ton of iron varies from 12s. to 40s. So it was in France, speaking of it before the war with Germany, where ironstone, yielding 35 per cent. of metal, was delivered at the furnaces at less than 3s. per ton, while at other works a ton of iron cost 44s. for the ore they were smelting. The relative advantage enjoyed by either nation must, therefore, be determined by the proportion of the cheaper and dearer varieties consumed. After a very minute investigation on this point, Messrs. Gruner and Lan, in the work already mentioned, settled the average difference in favour of France, at 8s. (10 fr.) on the ton of pig iron; and according to these very competent authorities, Belgium is stated as being then equally favourably situated in respect to the cost of its ore. The German works on the Rhine have to deal with somewhat more expensive sources of iron than either of the other two countries, but this inferiority of position is partly neutralized by cheaper fuel, as will shortly appear.

And now a few words on the question of coal, which, during the last twelve months, has proved an object of such absorbing interest to the whole civilized world. Of this material of the ironmakers' art, Great Britain furnishes, in round numbers, twice as much as Belgium, France, and Germany put together. This she is able to do by virtue of the number and extent of her coalfields, but it is a fallacy to suppose the iron trade of the British empire has expanded to its present proportions in consequence of coal being worked much more cheaply than is the case in the three other States with which we are comparing it. To place this clearly before the meeting, I will give the cost given me of raising a ton of coal in different places during visits paid in the year 1867.

		s. d.
Belgium—5/7¼, 7/1¼	Average	6/4¼
France—3/0½, 4/2, 4/9½, 5/0, 5/2½, 5/4¾, 6/0¼, 6/7¼, 6/7¼, 6/9¾	„	5/4½
Germany—Rhenish Prussia—4/8, 4/8, 4/9½, 5/0, 5/7	„	4/11½

In Great Britain, at the same time, we should probably not be far from correct in accepting 4s. as the average cost of delivering the fuel at the pit's mouth in the chief ironmaking centres of our own country.

To all these figures has to be added the cost of conveying the coal to the ironworks, and this, in the case of Belgium and Germany generally, will be done as economically as with ourselves, inasmuch as the furnaces and mills, like our own, are placed on the coalfields. In France, on the other hand, the fuel has occasionally to be conveyed considerable distances, but in some cases the ironworks are established near the coal mines.

The expense of transport, in this last-named country, sometimes amounts to as much as 8s. (10 francs) per ton, but this high charge is usually met, to some extent, by an advantage in the price of the ore.

The truth, however, is, that if we wish to arrive at a sound appreciation of the subject under discussion, we must dismiss from our minds all question of cost and confine our attention to the market value of coal, a value which of course is determined by the relation borne by the demand to the means of meeting it. In France, the supply is so far below the requirements of a large nation that a considerable deficiency has to be made up by importations from abroad, incurring thereby a heavy charge for carriage. Coal under these circumstances was, according to Messrs. Gruner & Lan, fully double the price it commanded in England in 1862. The difference between the cost and market value at the pit I found in 1867 was from 4s. 6d. to 5s. per ton. Belgium and Rhenish Prussia, on the other hand, are both coal exporting countries, and were able to raise the mineral at the period we are considering in such quantity that the margin between the cost of production and sales was from 2s. to 2s. 6d. per ton in the former, and from 2s. 3d. to 2s. 9d. in the latter.

Ore costing, according to the French authors referred to above, 8s. less on the ton of pig iron than the average of that smelted in

Great Britain, gave this country with its cheaper coal in 1867 an advantage not exceeding, on our entire make, a few shillings per ton over Belgium; and in Rhenish Prussia the lower price of fuel would go far towards enabling the German smelter at that time to work as economically as the manufacturers near Liége and Charleroi.

Thus it will be seen from what has preceded, that Great Britain owes the pre-eminence she has hitherto enjoyed as an iron-making nation, not so much to her ability to work coal greatly below the cost of that obtained from the mines of Belgium, France, or Germany, but because she possessed, what hitherto may have been regarded as, unlimited powers of production in respect to her fuel.

A complete revolution in prices has occurred since the date of these comparative estimates. Notwithstanding the enormous coal-producing powers of Great Britain, the demand upon its resources has overtaken, indeed, gone beyond, its present means of supply; and to the infinite amazement of every one, the selling price of furnace coke rose in the chief seat of its manufacture, viz., the county of Durham, to about double that charged two years ago to the least favourably situated ironworks in France. It may be further observed as a fact worthy of notice that according to the price currents of the day coke is as dear in the North of England as it is at Charleroi.

Included in the requirements made on the British coalfields are some fifteen millions of tons taken by foreign countries, a quantity which it is needless to say is far in excess of the deficiency which has been the cause of fuel rising with us to fully three times its former figure. Leaving on one side the imprudence, indeed the impossibility of such a change in our commercial policy as that of forbidding the export of coal, it is open for us to imagine the probable result of such a course of action. The 15 million tons would be thrown on our hands and the Continental ironmasters would have to compete with those of our country; the latter drawing their supplies of fuel from an overstocked market, and the former from one with coal at famine prices.

It may be alleged, and with reason, that the recent exorbitant prices are opposed to the public good, but we must look to the natural course of events and not to legislative interference for working the cure. What I would respectfully submit is that most

instructive lessons in the all-important science of political economy are involved in the experience of the last year or two. As this address, however, is not intended to be of an argumentative character, and I have already exceeded the time allotted to me, I must take leave of the subject by commending it to the earnest consideration of the members of the Institute, foreign as well as domestic.

It now only remains for me to express the grateful sense we, representing the Iron and Steel Institute, entertain of the hospitable and kindly feeling which prompted our Belgian friends to invite us to visit their country. In order to lend dignity to the occasion, we have had the honour of being officially received by the Mayor and municipal authorities of Liége. This great act of courtesy, emanating as it does from the governing body of one of the most important cities in the kingdom, demands at our hands the most cordial acknowledgment. By virtue of the honourable office I hold as your president, I ask to be allowed formally to thank the iron-masters and other gentlemen who have generously promised to afford us an opportunity of inspecting their respective establishments. This simple expression of feeling will, I feel confident, be warmly supplemented personally by individual members of the Institute. They no doubt, like myself, will impress on our present hosts the gratification they would experience on receiving within their works any one connected, however remotely, with the great metallurgical and mining industries of Belgium.

After Mr. Bell had concluded his address, M. Trasenster, the president of the Reception Committee, delivered the following reply:—

Mr. President and Gentlemen,—I shall commence by expressing to the President our profound gratitude for the kind and cordial words which he has thought fit to address to us. Most of those whom to-day you so kindly invite to become your collaborateurs have already enjoyed your great and sincere hospitality, and I can assure you that our industrial classes and population generally consider it a great honour that you should have chosen Belgium as the scene for this gathering of the Iron and Steel Institute, and they seize with ardour this occasion to exhibit to you their sympa-

thetic and friendly sentiments. Belgium, free and independent, owes a special debt of gratitude to England, while Belgium, frugal and manufacturing, gladly acknowledges the services rendered by your country, and especially by the members of your Institute, to the cause of progress and civilization. You have assisted in the emancipation of Belgium with a solicitude which has never wavered; recent documents have proved that ever since 1830 your country alone has constantly protected us against the unhealthy covetousness or rancorous politics of neighbouring powers; at divers epochs—notably at the times of the great questions of Luxemburg and the railways, and, more recently still, when two great Continental nations gave themselves up to one of the most formidable wars in history—England interposed its protection; she would, if it had been necessary, have thrown the weight of her cannons into the scale to protect a small, but, happily, independent, nation against the culpable projects of a criminal policy. We entertain towards the English nation and its Government a feeling of profound thankfulness for the energy with which it has protected the weak against the abuse of strength. From a general point of view, there are abundant motives why the representatives of the great iron and steel industry should find with us a hearty and enthusiastic welcome. Citizens of a free country, Belgians never forget that you have most gloriously maintained and developed political liberty at the times when its future seemed most dark over all the Continent. You have been the great school of those noble and immortal institutions which, in assuring to men respect, dignity, and the full exercise of their faculties, open up and stimulate sources of manufacturing industry. It is because the Englishman is a self-reliant man, because he is accustomed, by the exercise, sometimes even roughly put forth, of political power, to solve all problems, to reason out and compare different systems, to exercise constantly his own will, and to take the initiative, that his country has become the first in the world in great industries. Some countries have fertile plains, others have rich repositories of coal and precious metal, others again ports and rivers; but, nevertheless, industry is there yet in its infancy; mines are scarcely opened, means of communication are primitive, and all this because they are peopled by creatures brutalised by despotism; because they are wanting in men—that is to say, beings habituated to the exercise of their own will and intelligence. It

has been said that the world belongs to energy, and no people has more distinctly proved the truth of this adage than the English. Whether in the throes of war, or the occupations of peace, England has had for its distinctive character that indomitable perseverance and energy which triumphs over all obstacles. England, which saved the liberty of the world from the tyranny of a despot of prodigious genius, shines in the foremost rank both of economical reform and technical inventions. Thus we see that in the great industries of iron and steel, of which we have here to-day some of the most eminent representatives, the greater part of the important improvements have come to us for the last century from England. It is from your country that the coke-burning blast furnace emanated ; also the process of puddling with coal, which has enabled us to produce iron at a low price, and to render it capable of being turned to uses so various and considerable. It is in England that the steam engine, railways, locomotives, steam navigation—all those stupendous agents for conquering matter and bringing men and things nearer together—have been either invented or have received the greater part of their perfection. When iron was found to be insufficient in supplying all the exigencies of mechanism and the colossal railway system, an invention, the immortal author of which, Mr. Bessemer, is unfortunately kept away from us by illness, enabled us to obtain, at a small cost, a metal more durable and tenacious than iron. In order to render unnecessary the severe labour and great cost of production which was formerly required, an American member of your Institute, Mr. Danks, whom we are happy to be able to salute here to-day, has perfected the rotary puddling furnace in such a manner as indicates the speedy acceptation of that process as one of the great industries. The questions which are attached to the utilization of fuel have acquired an importance which increases day by day. Your worthy president, Mr. Bell, by his learned and laborious researches, has contributed to the elucidation of that part of the mystery which still hangs over the operation of the blast furnace, and the inventions of one of your illustrious members, Mr. Siemens, has completed a new era in the employment of means of procuring heat. You have thus merited well of humanity in the progress which you have realised in the colossal industry of which you are the representatives. But it is not only by your discoveries that you have acquired the right

to the general gratitude, it is also and above all by the open and generous manner in which, thanks to your Institute, you have placed them at the disposition of the Continental industries. England has often been accused of egotism, and there was a time when her foreign policy gave a certain ground for these accusations; but now, for more than thirty years, she has given to the Continent an example of great economical progress. In spite of the ties which appeared to unite protective duties with the social constitution of England, she has, the first of all, inaugurated commercial liberty, after a struggle which will ever remain as one of the most memorable examples of the power of just ideas in a country which understands and practises free discussion. She was also the first to invite all the people of the world to those grand industrial tournaments destined to the glorification of labour and human intelligence, without distinction of nationalities. The founding of the Iron and Steel Institute was the consecration of an epoch in progress which almost amounted to temerity. The ironmasters of England, far from continuing to consider themselves, as of old in all manufacturing countries, as jealous and hostile competitors, have loyally united themselves together for the purpose of self-enlightenment by study, and by discussion on their manufacturing processes. They join in common their acquired experience, increasing their knowledge of everything by their reciprocal services, and ameliorating without cessation the conditions of labour. To-day you have made one more step in the practice of those strong and broad ideas which still astonish those producers who remain behind in the paths of the ancient routine. You no longer content yourselves with calling together your compatriots for discussion on industrial innovations, for the consideration of duties, or of exhibitions, for example ; your meetings take a higher and more extended scope, and, by a privilege which we duly appreciate, you have done Belgium the honour to make it the first country in which your Institute has met upon the Continent. You have generously placed before us the treasures of your experience, and the results of your initiative power, being, at the same time, desirous to make yourselves acquainted with the industrial condition of our little country. You knew beforehand that you would not find here those colossal establishments devoted to one sole speciality of production ; our establishments, compared with yours, are modest ;

they also have not so vast a connection, and have, therefore, to fight against the cost of material, but on that account you will find that particular care is taken in the purification and carbonisation of the fuel, and much attention is paid to economy in the details of working. In any case, this international meeting commemorates an elevated and fruitful idea. It is one step further towards affirming the union of different peoples in the paths of peace and labour, and will contribute to extend towards European nations that community of interests which the timidly prejudiced have too long misunderstood. Europe, that hive of industry, is, after all very small when it is compared with those immense countries which for thousands of years seem, like the Egyptian mummies, to escape the influence of external events. Countries covered by innumerable populations, encompassing inexhaustible wealth, have neither mines in work, nor steam engines, nor railways. Man tills the ground, and transports the produce as in the Biblical times ; many generations are born and die without adding anything either to the knowledge or to the well-being of their predecessors. Do we not find, then, (and I do not think I am guilty of an indiscretion in saying that I am quoting an august writer), an immense field for European activity to cultivate and cause to fructify, when instead of invading these countries for purpose of aggression, oppression, and intolerance, she takes with her ideas of peace, benefit, and civilization ? In the far East, we see Japan awake as out of a long sleep, and come to seek the elements of regeneration by contact with European society. By its side, an empire with a larger population than that possessed by entire Europe, had until now opposed to all innovation coming from abroad a defiance fierce and insurmountable. Now, this defiance appears to diminish, and with due care and prudence it may finish by disappearing altogether, and opening to our industries a considerable opportunity for advancing. To this end an ingenious idea, and one which may have excellent results, has sprung up in England. In order to familiarise ignorant and timid, although laborious, populations with the great European inventions, a subscription, supported by the English aristocracy and iron manufacturers, is about to be made for the purpose of collecting 1,500,000 francs to make a wedding present to the young Emperor of China. This present will consist of a portion of a railway, with locomotives, carriages, &c., and thus

giving an exact idea of this prodigious means of transport. The Belgian manufacturers will be, it appears, permitted by our powerful neighbours to join in this movement. In this state of things, does it not seem that there exists amongst the European industries a unanimous effort to import into many countries, resting in their infancy, the benefits of civilization and of perfected work? However, I must close, gentlemen, in order not to trespass too long upon your time, and reiterate to you the assurance that you will find everywhere in Belgium the welcome to which you have so many titles, not only on account of the numerous services your country has rendered to ours, but also for the benefits which you have bestowed on the industry and economical relations of other people, and the grand and generous idea which has prompted your reunion on the Continent. Again, gentlemen, I bid you welcome.

Votes of thanks were unanimously passed to Mr. Bell and M. Trasenster for their addresses.

M. Trasenster announced to the members of the Institute that he had received orders from His Majesty the King of the Belgians to invite them all to a Reception, which would take place on the following Thursday evening, the 21st of August, at the Palace at Brussels; that they would be all received on simply showing their card as members of the Institute, and that a special train would take them to Brussels and bring them back to Liége after the Reception.

The Scrutineers appointed to examine the voting papers, reported that the following had been duly elected members :—

Armstrong, Joseph, Brinsworth Iron Works, Rotherham.
Baare, Bernhard, Bochum, Westphalia.
Bagley, Charles Jno., Tees Bridge Iron Works, Stockton-on-Tees.
Baird, William, Albert Place, Airdrie, N.B.
Barkley, Jno. Trevor, Reform Club, London.
Barningham, Thomas, Darlington.
Barrett, Henry, Beech Street, Barbican, London, E.C.
Bishop, Frederick, the Mount, Stoke-on-Trent.
Crawshay, Arthur, Gateshead.

Copeland, Charles J., Barrow-in-Furness.
Darling, Wm. Littell, Dowlais.
Dobbs, Henry, Walker Iron Works, Newcastle-on-Tyne.
Dudgeon, Alex. J., 3, New London Street, London, E.C.
Ehlers, Emile, 51, Rue de la Loi, Antwerp.
Ellis, William, Victoria Street, Darlington.
Gooch, Jno. Virett, 105, Pall Mall, London, S.W.
Gordon, Joseph G., Totteridge, Whetstone, N.
Grice, Edwin J., Newport, Mon.
Hallam, Thomas, Middlesbrough.
Halpin, Druitt, 61, Cambridge Road, Hammersmith, London, W.
Hathorn, Jno. Fletcher, Sun Foundry, Leeds.
Higgins, James, Stocks House, Cheetham, Manchester.
Hodgson, John Lee, Apsley Terrace, Eaton-Chapel, Stockport.
Holley, A. Lyman, New York.
Hollingsworth, A. T., 37, Bedford Street, Strand, W.C.
Houghton, John, The Beeches, Moore, near Warrington,
Hutchinson, E., Skerne Iron Works, Darlington.
Jackson, R. W. (M.P.), Carlton Club, Pall Mall, London, S.W.
Jackson, W. F., Atlas Works, Sheffield.
Johnson, Walter, Forest Iron Works, Pontypridd.
Kershaw, Wm. A., Barrow-in-Furness.
Ledger, Joseph, Workington.
Lees, Eli, Oldham.
Liddell, Charles, 24, Abingdon Street, London, S.W.
Martin, A. H., Dowlais.
Maylor, John, Churton Lodge, by Chester.
Marsh, T. E. M., 34, Grosvenor Place, Bath.
Mitchison, H. S., Bowling Iron Works, Bradford, Yorks.
Moon, Richard, jun., 171, Upper Parliament Street, Liverpool.
Nordenfelt, Thorsten, Solna, Roehampton, Surrey.
Olrick, Lewis, 27, Leadenhall Street, London, E.C.
Paris, James, Dunkirk Iron Foundry, West Bromwich.
Peake, E. Copson, Rugeley.
Pearson, Thos. H., Dallam Forge Company, Wigan.
Penman, John Hugh, 2, Clarence Buildings, Booth St., Manchester.
Peterson, Martin, Custom House Court, Newcastle-on-Tyne.
Petin, Jean J. Hippolyte, Rive-de-gier, Loire, France.
Platt, Samuel R., Werneth Park, Oldham.

Ripley, Hugh, Acacia, Apperley, near Leeds.
Rogé, Xavier, Pont-a-Mousson, Meurthe, France.
Sacre, Edward, 20, Parliament Street, Westminster, S.W.
Schmitz, Emile, Middlesbrough.
Shaw, James, 150, Leadenhall Street, London.
Stanley, J. M., Morfa Lodge, Rhyl.
Steward, W. Crozier, Cartgate, Whitehaven.
Stewart, Andrew, 37, Oswald Street, Glasgow.
Stewart, James, 37, Oswald Street, Glasgow.
Stonehewer, Thos., jun., County Iron Works, Great Bridge, Tipton.
Stonehewer, William, County Iron Works, Great Bridge, Tipton.
Sutherland, The Duke of, K.G., Trentham Hall, Staffordshire.
Swan, Edward Willis, Middlesbrough.
Swan, Herbert A., Middlesbrough.
Taylor, H. Enfield, Aberystwith.
Thorburn, Jno., Ditton Brook Iron Works, Ditton Brook, Warrington.
Vaughan, Cedric, Hodbarrow, Cumberland.
Watteeu, Emile, Middlesbrough.
Wedekind, Hermann, 4, Great Tower Street, London, E.C.
Webb, Henry, Irwell Forge, Bury.
Williamson, J. D., Cargo Fleet, Middlesbrough.

In the evening, the members were entertained at a musical *fete* in the Jardin d'Acclimatation.

TUESDAY, 19TH AUGUST, 1873.

The members met at the Salle d'Emulation, Mr. I. Lowthian Bell, the President, in the chair.

The proceedings were opened by the reading of the following paper:—

BELGIAN MINERALS.—GEOLOGICAL REVIEW.

BY M. RENIER MALHERBE, Engineer in Ordinary to the General Survey of the Belgian Mines.

BELGIUM contains the most varied as well as the most productive mineral riches. They have fed the activity of past generations; they multiply, now-a-days, by incessant development,—the limits of which seem to be undefined. The history of the mining labour in Belgium might be embodied in saying, that it would be easier to point out which underground substances are not brought into use there, than to draw up a list of the natural products brought into the service of her industry by the Belgian sub-strata. From the point of view of their legal definition, they may be classed in three categories: the mines, day-levels, and stone quarries. The Administration of the mines, which has the upper survey of the under-ground workings, comprises two Directions; the first contains the province of Hainaut, the second, the provinces of Namur, Luxemburg, and Liége.

The Belgian mineral substances are deposited in three geological forms: in layers, or stratified, in pockets, and in veins. In layers are found: sands, clays, limestone, psammites, freestone, schist, slates, iron ore, manganese, lignite, and coal. In pockets are found: sands and clays, Plutonic rocks, certain iron ores, zinc, lead, and manganese ores. In veins are found: iron ores, blende, calamine, more or less pottery mine, pyrites, &c.

From an industrial point of view, those products may be divided into two great classes, viz., those applied to building purposes, and those used in metallurgy and chemistry. In the 1st class are found:—

1st. The sands existing specially in the quaternary and tertiary soils, used in glass-making, casting, and making of mortars.

2nd. The clays are principally found in the secondary and tertiary soils; besides the fullers-earth, much liked by cloth manufacturers,

the clays of the shores of the Rupel and Scheld enjoy a justly deserved reputation for potteries, tile, and brick-making. The Geyser clays are used in the manufacture of fire-bricks and other refractory products; the Eurite clay in the manufacture of china, &c.

3rd. The calcareous clays of Tournay, Namur, Samson, Horion, Hozemont, Soignies, Ecausines, and Sprimont, belonging to the primary soil, are liked at home and abroad for building purposes. The granite is much required on account of its great resistance to pressure and atmospheric agencies, for its elasticity and the large blocks found in the quarries. A magnesiferous chalk, found in kidney form at the base of the Romelian clay, has led to the establishment, at Antwerp, of a trade in cements, which rival the best English cements. The limestones are also much liked, from the greasy kinds to the most hydraulic ones. Numerous varieties of marble are found in our calcareous strata. These products are exported widely; some of them are possessed of a very fine grain and a faultless beauty of polish.

4th. The psammites of the primary soils, the use of which for paving stones has taken an enormous development, especially on the borders of the Ourthe, find a continuous outlet into Belgium, France, and Holland, where they compete with our volcanic rocks of Quenast and Lessines for the same purpose. The pudding earth of Marchin is exported into the neighbouring industrial centres for the manufacture of blast-furnace tapholes.

5th. The Belgian slate quarries, the products of which belong to the first layers of the sedimentary deposits, have been very largely opened up in the environs of Vielsalm. Those of Herbeumont are superior both as deposits and as to quality. The coticule, or razor whetstone, is very much sought for by English knife manufacturers.

In the category of mineral substances used in metallurgy and chemistry, we meet with, first of all, iron ores. The oligiste (specular ore) and carbonated iron, are found in the primary soil in layers underlying the schistose beds. Generally the limonites form pockets, sometimes connected with carbonated iron. The iron veins are entirely limonitous. The most important deposit in the shape of layers is that of oligiste (specular ore), which, in the environs of Vedrin, is remarkable for its unbrokenness and extent. It is composed of several layers more or less near each other in stratification, corresponding with the quartz-schistose-condrusian stage.

Its northern flat joins nearly vertically the bed of the southern border of the carboniferous basin, to which it serves as a cover. The use of the oligiste is becoming very extensive, and it is exported into France and Germany. The limonite is found specially in pockets, sometimes in a state of real veins, and formed by the decomposition of the pyrites. It produces strong iron of an excellent quality. Its extraction is nearly entirely used up by the Belgian ironworks. Its principal beds may be grouped as follows:—

(*a*). Ores of Entre-Sambre et Meuse.
(*b*). „ the Scheld.
(*c*). „ the Meuse.
(*d*). „ the Ourthe.
(*e*). „ the Vesdre.
(*f*). „ Luxemburg.
(*g*). „ the Campine.
(*h*). „ Brabant.

The carbonated iron is only met with in partial beds; the sparry iron ore of the coal mines accompanies some beds, of which it pervades the roof and the wall.

Immediately after the iron ores follow in importance the zinc ores. The principal lode is that of Moresnet, immense accumulation of calamine deposited in a narrow band of limestone. The Welkenraedt lode, also in the form of a sack, is owned, like the former, by the Vieille-Montagne. Amongst lead mines known thus far, one of the richest is that of Bleyberg, which is a vein of galena and blende traversing the coalfield until it reaches the limestone. The Nouvelle-Montagne owns, at Engis, minerals similar to the former, deposited at the juncture of the limestone with the coalfield. New lodes have been opened out by the company in contact with the dolomite. These sulphurets are partly transformed into oxydised ores above the natural water level. Galena and blende associations are likewise found in the form of veins in the mines of Velaine and Rona. Some of the former sulphurets contain pyrites connected in variable proportions. The lodes of Rocheux and Oneux have a special reputation in England, Prussia, and Germany, as producers of pyrites. The chemical manufacturers like those sulphurets deposited in important veins, and taking sometimes the shape of an extensive pocket. Many other mines work in Belgium the sulphurets named above, the mechanical preparation of which

produces the separation. I may also mention the manganese mines, the working of which is sure to become very important on account of the extension now taken by steel works, claiming daily a larger make of pig iron specially suitable for that metal.

Whatever may be the importance of the mineral substances roughly enumerated above, there is none deserving so much attention as the coal deposits. The coal formation occupies, in Belgium, a very considerable area in the three provinces of Hainaut, Liége, and Namur. A small basin situated in the province of Luxemburg must also be mentioned. This formation shows a break of continuity not far from the village of Samson, between Ardenne and Namur, which break took place by the upheaving of a calcareous saddle. It follows, therefore, that, geologically speaking, the Belgian coal deposit comprises two basins. I will call the first the Eastern basin, beginning at Samson and pursuing its course through the province of Liége, towards the Prussian frontier, beyond which the deposit of Eschweiler must form its continuation. I call the second the Western basin, comprising the provinces of Namur and Hainaut, whence it branches off into the French coalfield towards Valenciennes. The Belgian deposit comprises some fifty beds, exclusive of the series of Flénu, localised in Hainaut; they vary between 0·50 and 1·00 m. thick. The corresponding normal thickness of the coalfield is 1,200 m. This immense carboniferous band, very much elongated from South West to North East, *i.e.*, following a great arch of a circle from Valenciennes to Aix-la-Chapelle, passing in the interval through Mons, Charleroi, Namur, and Liége, rests on a calcareous or carboniferous bottom. The parts worked on a cross section to this direction, show a comparatively little width. It is just possible, however, that this deposit may be continued to the North on a much larger width. I therefore conclude that, at present, the total carboniferous riches of Belgium cannot yet be ascertained; on the other hand, it may be affirmed that we need not, in our country, get uneasy about the supplies of fuel running short.

The geological constitution of the sedimentary deposits comprises two very distinct drifts, and which have been well defined on the entire stretch of the extreme borders where the workings have been pursued. The first drift comprises the large flats, or the northern zone of the deposit. The second drift comprises the southern

zone in stratification, corresponding, local accidents excepted, with the calcareous, near to which have been established, on a large scale, alum and metal works. If the southern limit of the coal formation be, so to speak, everywhere the same throughout Belgium, it is not so with the northern formation. In that region, the calcareous, forming the seat of the deposits, is only accidentally identified. The flats in the north do not crop out everywhere on the surface. They are often hidden by a deposit of secondary, tertiary, or quaternary soil; sometimes this deposit obtains a considerable thickness. This is specially the case in the north of Mons, and, thanks to the ingenious sinking apparatus applied by M. Chaudron, the coal trade is able, in Hainaut, to open up daily new fields for the working of the miner. Between the two large drifts named above, bordering the Belgian coal deposit, more or less developed basins and saddles squeeze themselves in, the study of which gives the key for the anatomical descriptions of this deposit. These accessory basins and saddles, the formation of which is particularly the result of the phenomena of compression and upheavings, to which the coal formation was exposed when still in a plastic state, are very capricious as regards their number, the direction and inclines of their axes. The irregularity which they show is proof that the phenomena of which we speak have varied in intensity and direction from one point to another, without it being yet possible to determine everywhere the zone of influence of the concurrent powers, the general result of which has given to the deposit the irregular form which the workings discover in it.

The large flats of the North present, over the whole area of the Belgian deposit, a sloping of a uniform regularity. It is the only portion which seems to have escaped the geological perturbations which have followed the coal formation. Accessory flats and straights are found in succession towards the South, sometimes in very uneven drifts, and which in this case always contain larger coals, the working of which is more dangerous, owing to the presence of fire-damp. The connection of accumulation, in identical conditions of the lodes, of the bituminous elements and fire-damp, is well worth attention. This summary description does not permit me to follow up to their generation the numerous basins and saddles of the coal formation; be it sufficient to state that their axes are very nearly parallel to that of the central or principal coalfield,

which surrounds very much the arc of a circle mentioned above, and limiting the deposit itself.

Only certain parts of the formation are excepted, as, for instance, that of the flats of Herve, in the province of Liége, which, owing to the irregularity in the direction of the axes of the basins and saddles, seem to defy a systematic description, because, having been compressed in many converging directions, the primitive regularity of generation cannot be traced. Similar anomalies are met with in Hainaut.

Independently of the difficulties which are met with to trace, by means of the elongation of the formation, the correlation of the congeneous basins and saddles, the existence of long lines of breakage and falls complicates, in a great measure, the study of that basin from the point of view of the similarity of the beds.

The most important faults follow, in a very parallel manner, the general axis of the formation; others have a direction almost perpendicular to the former. The first are most important on account of the vertical throw; this circumstance, together with the modifications which the same bed shows on one side and on the other of the break, explains the difficulties which the owners meet with at the junctions. One fact well worth notice is the variable height of the throw from one point to another of the disturbance. These geological faults must have manifested themselves after the plastic period, because the rocks have been broken by them. To explain the geological phenomena to which the Belgian coal deposit was subjected after its formation, many theories might be brought forward, but it seems to me as if none could, as yet, give a correct account of the results discovered by observation. I will say the same of the causes that have modified the physical and chemical nature of similar beds to such an extent as to render them sometimes different in aspect and in use. Thus, although the beds of the Herve Flat have their equivalents in the Seraing basin, the greatest disparity exists between those two formations from a mineralogical point of view, as well as from that of the industrial applications.

These facts account for the difference in the general resemblance not only between the coal formation of Hainaut, Liége, and Namur, but also between the beds of one and the same province.

No doubt it is understood that in the order of succession and for identical drifts we fall in at the top of the deposit with coals essen-

tially gaseous, as shown by those of Flénu; underneath, the coking coals, and then a series of half-coking combustibles, and, lastly, at the bottom of the formation, hard coals. Such successive modifications can be explained through the metamorphic phenomena; but when we fall in with sudden modifications in one and the same element of the formation, one is in the presence of a yet unexplained fact. The study of a coal-bed is, therefore, enormously interesting on account of the geogenic deductions to which it will supply some day the finishing stroke. The explanation of the phenomena of dislocation experienced in the coalfield, and that of the physical and chemical alterations in one and the same bed, establish questions that are very interesting for geologists. From an industrial point of view the anatomical study of the coalfield will give to the working a certainty of precision, such, that it may be foretold beforehand, that at such a depth, at such a point, such a bed of the formation will be found. The uncertainties on this head will continue to exist as long as detailed maps, based on precise and intimate studies of the formations, shall not have been got up for all the carboniferous zones. It will be understood that labours of that kind can only be undertaken by public administrations embracing in their action all the elements of the problem, and having at their command sufficient financial resources to carry out in a satisfactory manner such an undertaking.

In 1861, the Belgian Government entrusted to Mr. J. Van Scherpenzeel-Thym, at present chief engineer, director of the provinces of Liége, Namur, and Luxemburg, the heavy task to study the technical means to be used for the making of a general map of the mines of Belgium. The work is at present on the way to execution for the two provinces of Liége and Hainaut. Some parts of the coal deposit have already been sufficiently studied to have found, if not the last word, at any rate data very near the mathematical truths which the author of the project has made his goal. I owe to my official connection with this work the honour to speak on this occasion. In every mining country where works are opened out, the geologist possesses, as resources, independently of the above and underground observations, the study of the plans representing the works. The latter being always enclosed within a certain zone, there remain numerous gaps often considerable and unexplored. To establish, therefore, by induction,

the probable drift of the beds in the latter, it is indispensable that the greatest precision be brought to bear in the study of the explored or worked parts to discover the law of formation of the unexplored parts. The paleontological character, in spite of the sceptism which has been shown it hitherto, will very probably serve to mark the great divisions of the coal formation, and to unite distant basins. I hint especially to the shell beds pointed at in our country in the province of Liége and Hainaut. May I be permitted, in finishing, to express my regret that the several Governments which have taken in hand the execution of detailed mining charts, have not considered beforehand the means of execution. In this manner comparative results of generalisation might more easily have been obtained.

In order to facilitate the appreciation of the productive value of Belgian mining, I cannot do better, I think, than by supplying the following statistical information taken from the official documents, which I am indebted for to M.M. the chief engineers, viz:—

In 1872, the Belgian coal trade has supplied 15,658,948 tons, representing, roughly, 205,000,000 francs. The working people occupied in this trade were in that year about 100,000 individuals. The metal mines have supplied to the works:—

105,144	tons of	washed iron ore,	worth	1,381,765	francs.
6,497	„	lead ore	„	1,656,583	„
55,522	„	zinc	„	3,765,746	„
25,437	„	pyrites	„	551,541	„

The quarries have supplied produce worth 7,850,000 francs. The number of steam engines used by the Belgian trade, in 1872, represents a total strength of about 150,000 H.P., divided over more than 6,000 machines.

The thanks of the meeting having been unanimously voted to M. Malherbe for his paper, the following paper was read by M. Habets :—

THE OOLITIC IRON ORES OF LUXEMBURG AND LORRAINE.

BY M. A. HABETS, LIÈGE.

THE production of pig iron in Belgium amounted, in 1871, to 610,000 tons, while the output of native iron ore did not exceed 1,000,000 tons. That quantity being quite insufficient for the requirements of the country, the deficit of ore required—nearly 600,000 tons—is supplied principally from the oolitic iron ores, which are worked in the Grand Duchy of Luxemburg and in the neighbourhood of Longwy. The consumption of oolitic iron ores corresponds, therefore, to more than one-third of the total production of pig iron in Belgium.

A short notice of the geological formation of this iron ore deposit, and of its working, will probably interest the members of the Institute. This rich region truly deserves the name of the *Cleveland of the Continent.*

Though situated on the same geological level, this iron ore deposit does not exactly occupy the same geological position as the *main seam* does in Cleveland. Instead of lying at the level of the middle lias, it is placed on the same level as the marly sandstone, and corresponds more nearly to the *top seam* of the Cleveland district. Most of the French geologists assign it at the upper part of the lias, whereas the Belgian and German ones generally place it at the base of the inferior oolite, in the Bathonian system of M. d'Omalius. In Belgium, this stage is known as *Psammite and oolitic limonite of Mont. St. Martin,* such being the name of a small village situated on the French frontier, near Longwy.

The deposit which contains the oolitic iron ore seams alternating with sterile beds, is found between two very hard marl seams. As from these seams water springs at two different levels, there

is an excellent guide for exploration. The ore does not lie directly upon the inferior marl; it is separated from it by a bed of psammite, often rather hard. This corresponds to the *Marly Sandstone* of the English, and to the *Supraliasic grit* of the French geologists.

From the presence in the iron and psammite seams of a certain number of liasic species, and also, perhaps, from the mineralogical likeness of both these marl seams, the French geologists conclude that this stage must be classed among the lias.

The Belgian geologists, and particularly so M. Dewalque, Professor at the University of Liége, base their conclusions on the existence of a certain number of new fossils, which spread in the Bathonian system, and place the superior limit of the lias immediately above the inferior marl seam. [Appendix I.]

Has the main ironstone of Cleveland its equivalent in the region which we are now considering? This is a most interesting question. We find, at Garnich, in the Grand Duchy of Luxemburg, a bed of iron ore in the stratum of middle lias, which is called, in Belgium, "Macigno d'Aubange;" this bed, as far as geological position is concerned, may correspond with the main ironstone of Cleveland. But the thickness of this seam is from 0·60 m. to 1 m., and can only be worked on a small scale in the neighbourhood of that locality. The ore is richer and purer than the oolitic stone, and a certain quantity of it is imported into Belgium.

This seam, however, does not present the same chemical and mineralogical features as the ores of Cleveland.

ANALYSES OF GARNICH ORE.

Volatile matter	8·20	13·60	12·09
Insoluble „	22·60	8·95	12·98
Sesquioxide of iron	50·25	50·40	67·62
Oxide of Manganese	—	—	1·74
Lime	10·85	18·30	1·57
Magnesia	2·00	1·73	0·49
Alumina	3·45	3·40	1·84
Phosphoric acid	1·55	3·32	1·58
Sulphur	0·15	0·40	0·12
	99·05	100·10	100·03

The oolitic ore found in Luxemburg bears the name of "Minette" from the circumstance that 20 years ago it was considered as being of a quality so inferior to the alluvial ores, which then supplied exclusively the blast furnaces of Luxemburg, that the name of Minette was given as a term of contempt, the word "mine" only being applied to the alluvial ores.

At the present time, the production of alluvial ores in the Grand Duchy of Luxemburg scarcely reaches 50,000 tons, whilst that of Minette amounts to more than 1,000,000 tons. There are some proprietors of works, nevertheless, who attribute to these alluvial ores certain good qualities, and add, in the blast furnace, homœopathic doses of this material; but at present, I dare say, the former opinion on Minettes has decidedly vanished.

Though there are very unmistakable traces of ancient workings of Minette, tradition putting them as far back as the Roman period, and though the Minette was worked a long time ago in Lorraine, it is the Belgian trade which has pointed out the great importance of the iron deposits in the south-western hills of Luxemburg.

In 1860, the blast furnaces of La Providence had already used this ore, but the extensive consumption of it dates from the year 1862, the period of the development of the iron industry in the Grand Duchy of Luxemburg, which was favoured by the extension of the railway system, and characterised by the transformation of the old charcoal blast furnaces into the coke furnaces. The first blast furnaces erected in Luxemburg specially for the use of coke, produced from 15 to 30 tons per day. In 1865, Messrs. Metz and Co. erected, at Dommeldange, blast furnaces to produce 70 tons per day, and in 1872, the Luxemburg Blast Furnaces Company erected blast furnaces at Esch-on-the-Alzette, to produce 100 tons a-day. In 1862, the Grand Duchy of Luxemburg possessed only four coke and three charcoal blast furnaces, producing on an average 42 tons a day; in 1873, there are 19 coke blast furnaces producing about 1,000 tons a-day, and new establishments continue to be both projected and executed.

The Minette iron deposit extends from Nancy up to Longwy, traversing the German Lorraine and the Grand Duchy of Luxemburg, and finishes in Belgium, although the geological stage to which it relates continues still on a pretty large scale. Like all seams forming the girdle of the basin of Paris, the iron deposit runs

from all parts to the centre, at an angle of from one to two degrees.

The plate (I.) shows the outcrop of the whole recognised iron deposit. The plate (II.) represents, on a larger scale, the part of the deposit bordering upon Belgium.

The whole formation may be divided into five groups :—

1. The group of Nancy.
2. „ „ Metz-Thionville.
3. „ „ Grand Duchy of Luxemburg.
4. „ „ Longwy.
5. „ „ Halanzy-Musson (Belgium).

Like all the silicious deposits of the jurassic period, which have covered the ground of the Luxemburg gulf, the Minette has attained, in the Grand Duchy of Luxemburg, a much greater thickness than in the neighbouring oceans, and that circumstance gives to this part of the field a considerable importance, considering its small area, which does not exceed 3,000 hectares.

The denudations and erosions which took place after the oolitic limonite deposit, and which have caused the Alzette valley to be formed, have separated the deposit of the Grand Duchy of Luxemburg into two chief districts :—

1. That of Esch-Rumelange,
2. „ Belvaux-la-Madeleine.

These winnings form, in the south-west of the Grand Duchy of Luxemburg, steep shores with irregular figures, which rise above the plain constituted by the inferior marl beds. Between these two districts, the steep shore forms, on the territory of German-Lorraine, the deep hollow which extends down to Villerupt, in France.

The considerable erosions which that formation has undergone, in the Grand Duchy of Luxemburg, has given rise to a great development of the line of outcrops. These outcrops present themselves in very steep shores, which circumstance is very favourable to the great development of open day-workings. Numerous excavations are made all along the irregular outline of these outcrops, which allowed of my procuring a great number of vertical sections, from which I have chosen some characteristic specimens, in order to give an idea of the variations of thickness and number of the ore seams from German-Lorraine down to Belgium. [Plate III. and Appendix II.]

I have taken, as a starting point, a section in Ottange (No. 1), near the frontier of Alsace-Lorraine, where we find the distance from top to bottom to be: 3 m. to 3·50 metres of silicious red ore, 12 m. to 15 metres of sterile beds, 5 m. of alternate psammite and smaller beds of yellow ore, then 3·50 m. to 4 metres of an excellent grey and green calcareous ore. In some neighbouring workings, a seam of 1·50 m. to 2 metres of calcareous red ore lies above the yellow ore, from which it is separated by 1·50 m. psammite. The grey ore is worked, under most remarkable conditions, by underground galleries throughout its whole thickness, which is sometimes 4 metres, and the roof is sustained by abandoned pillars of iron ore, without proppings. The quantity of ore thus left standing represents about 8 per cent. of all the ore in the mine. The green ore of Ottange presents something very curious in a mineralogical point of view. Its colour is attributed to its being formed, for a part, of silicate of iron (Berthierite). We often find traces of pyrites, chalko-pyrite and galena, and some specimens are said to give even the indications of mercury in the testing tube. If we go forward to the Grand Duchy of Luxemburg, we meet, in the whole winning of Esch-Rumelange, with the iron deposit divided into two levels, which are principally characterised by the colour of the ore, and separated from each other by sterile beds, the thickness of which diminishes from Ottange to Esch. These barren beds disappear in the west of that locality. In the lower level, the ore is grey or greenish; that of the upper level is red. It was ascertained that the development of thickness of these two seams is inverse; that where the red ore is met with, the grey is poor or deficient in thickness; but recent discoveries have shown the grey ore in some workings where it was unknown before, and where it has been covered by the sterile stones from the working of the red ore. The red ore presents also great variations as well in richness as in thickness. I have chosen some sections, taken from points not far distant from each other, to show these variations. Now, in the two sections near Kayl (Nos. II. and III.), the first one shows, above the sterile intercalation, a seam of 3 m. to 3·50 m. of red ore; the second gives but 1·30 m. of good red ore and many small seams separated from each other by barren beds. These small seams are found in all the workings above the more important seams, and, therefore, are easily won by open day-levels, otherwise they would be utterly lost if underground workings had to be

resorted to. The red seams are generally mixed with blocks of ferruginous limestone.

The deposit ends towards the top in the winning of Esch-Rumelange, by a seam very much mixed with quartz, which bears the name of the "silicious seam." This bed, which often attains a thickness of 2·50 m. to 3 metres, is capped by a bed of small flint pebbles, forming a very characteristic geological horizon. The bed is not worked, on account of the great quantity of silica which it contains. It is in the neighbourhood of Esch that the red seam is most developed, and its containing a good quantity of lime has made it specially useful to the trade. The grey seam also attains again greater thickness and richness in this locality, not far from the point where the deposit crosses the frontier of Alsace-Lorraine.

In the hollow limited by this frontier, we find principally the upper seams, as, on account of the inclination of the deposit, the inferior seams lie under water in the greater part of this region; the upper seams continue, however, to be found as rich as ever, and they are extensively worked in Audun-le-Tige, Russange, and as far as Villerupt, in France. They present a remarkable change in the colour of the ore—the red colour has become chocolate brown. There is also a slight alteration in its nature, the calcareous seams of Esch having become more and more silicious in approaching towards Russange. The promontory of Russange has another characteristic, which can be very clearly seen near Belvaux, the place where the deposit again runs into the Luxemburg territory, the layer having undergone a considerable rise, has emerged anew in the winnings of Belvaux-la-Madelaine, whereas the inferior seams lie under water in a great part of the winnings of Esch-Rumelange.

In that district there is no more separation between the two levels; the sterile intercalation has completely disappeared. In both the sections taken at Belvaux there is thus a thickness of 11 metres of ore without properly sterile beds. This deposit exhibits great variations in colour, which changes from grey to green and from red to brown and black. One of the lower seams is characterised by the presence of a great number of little veins of brown hematite, which are found with more or less frequency in the whole of the area of the winnings of Belvaux-la-Madelaine, whereas they are rarer in those of Esch-Rumelange. Towards the north of Belvaux, the deposit attains its greatest thickness at Differdange

and Niederkorn. In the sections which I have taken, the ore there attains, in several seams, the enormous total thickness of 17 metres. The minerals from some of these beds, however, require to be sorted by hand when they are worked. This is particularly the case with the seam in this region, occupying the upper part of the series, where it has not been removed by denudation. This seam consists of chocolate-coloured ore, named black ore, very friable, and containing numerous large boulders of limestone, ranged in the deposit in a manner which gives the appearance of limestone seams. It must be added that this limestone contains from 20 to 24 per cent. of iron, and would make a very good flux, if the chemical action of the lime which it contains, were not often partially neutralised by the alumina. This seam is the thickest in the hill named Klopp, near Rodange, where it is about 7·50 m. This section (No. 10) is also characterised by the presence of a grey seam at the basis of the deposit, which, starting from La Madelaine, presents very great regularity. But as to the chemical composition, the grey seam of La Madelaine contains more alumina and silica, and less lime, than the grey ore of Esch. That seam presents, moreover, the character of containing little veins of compact hematite, greatly increasing the richness of the bed. At the Klopp hill, the grey seam is from 4 to 6 m. thick.

In France, the thickness of the deposit decreases, and contains more and more alumina and silica. In the hill, named Bois-du-Chat, near Longwy, are the last extensive open day-workings of the deposit; at Mont St. Martin, it is principally worked by underground galleries, and only the richest part of the seam, which attains no more than 2·50 m. in thickness, is extracted. Opposite Longwy, is one of the most remarkable underground workings, which bears the name of Mexy. The ore here left unworked represents only 5 per cent. of the total quantity in the mine.

Towards Belgium, the thickness of the deposit decreases progressively, but the ore increases in richness; further on, at Musson, the ore disappears, and there remains nothing but the marly sandstone If in some places we again find a small face of ore, it is of so little thickness and so poor in quality that it is not worth the working. The area of the bed, which is situated in Belgium, does not exceed 300 hectares.

Such is a very short description of the deposit in Luxemburg and the neighbourhood of Longwy. The other groups present just as much interest; but we shall not enter into the same details, for they do not possess actually the same direct value to the Belgian trade. In Alsace-Lorraine, the deposit continues in the valley of the Moselle down to Metz, and is fairly rich in quality. At Hayange, the worked seam is 2·50 m. to 3 m. thick, whereas the same seam, at Ars-sur-Moselle, attains but 1·50 m. to 2 m. South of Metz there is a zone where no ore is found, but the deposit is met with again in the group of Nancy, on the borders of the Moselle and of the Meurthe, where, south-west of the town of Nancy, near Pont St. Vincent, it is again very rich and of remarkable thickness. This part of the deposit will perhaps agree, in Belgium, with the ores of Luxemburg, when the projected canal between Moselle and Meuse will be executed.

As to the chemical nature of the ore, we may state that the oolitic ore is hydrate of iron, mixed more or less with silicate and carbonate of iron, clay, and limestone or marl. (Appendix III.) The average quantity of metallic iron contained in it is 33 per cent., but some ores yield more than 40 per cent. The quantity of shells found in it makes the proportion of phosphorus rather large. The changes of composition are very frequent. Some portions of the deposit are very calcareous, others very silicious and aluminous, seldom silicious only, while there are also workings from which, at the same time, both silicious and calcareous ores are obtained, which can be put as mixtures into the blast furnaces. Some seams bear even their own flux, and are put without any mixture into the blast furnace. However, except in certain parts of the workings of Esch-Rumelange, it must be understood that the silica and alumina are predominant. Nevertheless, the use of sterile lime as a flux is very seldom resorted to in the Grand Duchy. In the neighbourhood of Longwy, the predominance of silica and alumina is so noticeable that the richness of the mixtures of ores decreases often to 25 per cent., by the addition of sterile lime, notwithstanding which the blast furnaces of Longwy are, of all the French blast furnaces, perhaps those which work the most economically.

The ore costs, on the average, 3 fr. per ton at the furnace, and the carriage of coke from the basins of Liége, or of the Centre, about 170 kilometres, costs close upon 8 francs 50 cents per ton, which carriage will now be reduced nearly to 6 francs 50 cents, because

the State has bought up the Great Luxemburg Railway. These cokes pay also duties of 1 fr. 30 cents per ton.

But the blast furnaces of Luxemburg are in a more favourable situation, as they are very near the workings, and there is therefore very little to pay for carriage. The ton of ore costs about 2 francs, and the carriage of coke from Liége to Esch (190 kilometres) actually amounts only to 7 francs 25 cents, which will be reduced to 6 francs 90 cents in a very short time. There is no duty to be paid.

The circumstance of the iron ore deposit covering the point of intersection of four different nationalities may give rise to most interesting studies of industrial economy. The Custom House question, for instance, would furnish a very good subject of consideration, as there could be compared the economical conditions of production, particularly now when the duty on pig iron into Germany has been abolished, and thus has modified the conditions by putting the French and Belgian blast furnaces on the same footing with the Luxemburg furnaces. They can now place their pig iron on the German market, which is one of the most important on the Continent. Such a study, however, would be out of place here. Another not less grave consequence of the influences which have tended to fix the line of frontiers, arises from the various conditions imposed on the production by the respective legislatures of France, Belgium, Luxemburg, and Alsace-Lorraine.

The law of 21st April, 1810, is now in existence in all these countries. It is well known that this law requires precision as regards the distinction to be made between the mines to be worked by the landowner and mines which are to be conceded by the State. In France, however, the law of 9th May, 1866, has completed this law, by sanctioning the practice which, since 1829, has ruled in France, not to grant any concession of iron ore deposits, without reserving the right of the landowner, who can get the mines by open day-workings, under the superintendence of the mining authorities as long as he can get any profit off it. Thus, certain concessions granted by the State never will become profitable, while the landowner will get the whole with profit by open day-workings. Much might be said, however, of the manner in which grants are given in France, and of the curious customs which the Adminis-

tration of Mines has established there; for instance, they will not give grants to any one who is not an ironmaster; but this would be again leaving our subject.

In Belgium, the case has been decided in a different way by the law of 2nd May, 1837, which law has provisionally reserved the concession of iron ore mines. This temporary settlement still exists, so that the iron ore mines cannot be granted in reality in Belgium.

The small deposit of Musson-Halanzy belongs, for the most part, to the Communes, who, as owners, have a right to work the deposit, and have conceded it to other parties, these parties paying Commune a royalty, and being compelled to work a minimum annually.

The same difficulty is met with in the Grand Duchy of Luxemburg, where the question has been decided in an entirely different way. The law of 15th March, 1870, introduced under the pressure of complicated local necessities, has declared that the deposit can be conceded in the workings of Esch-Rumelange, where the surface covers a thickness of 6 metres above the silicious seam, and in the working of Belvaux-la-Madelaine, when the excavation above the upper seam is greater than 24 metres.

Necessity has led to this arrangement, because the interests of the grantors and of private individuals had to be conciliated, the latter of whom had bought large areas of mining land at very high prices, with a view to get the ore by open day-workings.

We cannot but say, however, that these decisions are very arbitrary. The French law, which gives the right to the landowner to dispose of his land as long as he gets any profit off it, whatever be the depth of the cutting, is to be preferred in every respect. It is clear, indeed, that in certain parts of the deposit, one can work under 30 metres and more excavating, having regard to the richness and thickness of the ore, while in other portions the limit of 6 metres above the silicious bed, which is admitted in the workings of Esch-Rumelange, is far too great.

The law of the Grand Duchy of Luxemburg will form another source of legal difficulties between the concessionaires and the landowners, for there the exact delimitations could scarcely take place as long as the proprietors had not completed their workings.

As regards the parts of the country which can be granted by the State, the Grand Duchy has proposed to create sources of revenue by granting concessions, at a very high royalty per ton of ore.

Alsace-Lorraine has, up to the present, followed the French law in modifying certain formalities required in asking for concessions. There is, however, a new law under consideration, which will change the present regime. The new mining law of Alsace-Lorraine is based on the same principles as the Prussian mining law of 1865, which law in Germany is considered an improvement on the French law of 1810.

Now, the Prussian law of 1865 is precisely the opposite of the Belgian law of 1837, for it states that all the deposits of iron ore shall be conceded, without any exception, in favour of the owner of the surface. But the new law for Alsace-Lorraine, having to take into account the existing state of things, declares that the landowner shall have the right of working the iron ores in the open so long as his works do not impede the underground workings of parts deeper than the bed, which is nearly tantamount to the present French law.

I have just mentioned the different laws in force, to show how this circumstance may alter very much the economical conditions of the production in the different portions of one bed. In Belgium, the royalty is from 30 centimes to 45 centimes per ton in favour of the landowner. In Luxemburg, a concession may only be obtained at very high royalties, and these will be probably established by the high rates which have been paid for the parcels of land to be worked in the open. Of late, portions of land have been bought at the rate of from 35,000 to 40,000 francs per hectare. Fifty years ago, the owners of this land sold it at less than 50 francs per hectare, to get rid of the payment of the taxes which weighed on them.

In France and in Alsace-Lorraine, on the contrary, the grants are free, and there are very few lands left, which, by their position, can be worked in the open by the landowners. A great number of grants have recently been given in Alsace-Lorraine by the German authorities, and a list of them up to the 1st of August, 1873, will be found in Appendix V. The same ore, therefore, is charged with dues in four adjoining countries, varying between 0 and 30 per cent. of its value. Now, this is nearly everywhere the same, when the working is done by means of underground galleries. This variation produces, in the cost price of the ore, differences which are important enough to allow, in times of a crisis, countries like Alsace-Lorraine and France, which will enjoy free grants, to compete successfully with such as Luxemburg, which will levy heavy dues on the produce of ores.

APPENDIX I.

List of Fossils given in 1855 by Terquem.

SUPRALIASIC GRIT.

Belemnites tripartitus, Schl.
,, compressus, Sow. *B.*
,, abbreviatus, Mil.
,, nodotianus, D'orb.
Ammonites insignis, Sch.
,, radians, Schl.
,, opalinus, Rein.
,, normanianus, D'orb. *L.*
Dentalium entaloïdes, Desh. *B.*
,, elongatum, Munst.
Pholadomya lyrata, Low.
,, zieteni, Ag. *B.*
,, decorata, Ziet.
,, obtusa, Ag. *B.*
,, reticulata, ,,
Corbula voltzi, Terq.
Pleuromya unioïdes, Ag. *L.*
,, angusta, ,,
,, œquistriata, ,, *L.*
,, arenacea, ,, *B.*
Ceromya (greslya) anglica, Ag.
,, major, ,,
,, striata, ,, *B.*
,, pinguis, ,,
,, donaciformis, ,,
,, rotundata, ,,
Cardium truncatum, Ph.
Tancredia (Hettangia) dionvillensis, Terq.
,, compressa, ,,
Isocardia concentrica, Sow. *B.*
Trigonia navis, Lin. *L.*
,, litterata, Ph.
,, pulchella, Ag.
Arca Munsteri, Goldf. *L.*
,, elegans, ,,
Nucula Hammeri, Defr.
,, pectinata, Ziet. *B.*
Pinna fissa, Goldf.
Mytilus gregarius, Goldf. *B.*
,, cephus, D'orb.
Gervillia Hartmanni, Goldf.
Pecten paradoxus, Munst.
Ostrea cymbium, Var. dilatata.

OOLITIC HYDROXIDE.

Icthyosaurus communis. *L.*
Belemnites abbreviatus, Mil.
,, compressus, Sow. *B.*
,, exilis, Schl.
,, acuarius, Schl.
,, nodotianus, D'orb.
,, incurvatus, Quenst. *L.*
Nautilus inornatus, D'orb.
Ammonites opalinus, Rein.
,, aalensis, Ziet.
,, radians, Schl.
,, variabilis, D'orb.
,, concavus, Sow.
,, murchisoni, ,, *B.*
,, insignis, Schl.
,, jurensis, Ziet,
Pholadomya fidicula, Sow.
,, decorata, Ziet.
,, obtusa, Desh. *B.*
Pleuromya angusta, Ag.
Ceromya (greslya) anglica, Ag.
,, striata, ,, *B.*
,, pinguis, ,,
,, major, ,,
Isocardia concentrica, Sow. *B.*
Cardium truncatum, Ph.
Tancredia (Hettangia) dionvillensis, Terq.
,, compressa, ,,
Astarte lurida, Sow. *B.*
Trigonia navis, Lin.
,, tuberculata, Ag.
,, undulata, ,, *B.*
,, costellata, ,,
Mytilus gregarius, Goldf. *B.*
Gervillia Hartmanni, Munst.
,, tortuosa, Phil.
,, lata, ,, *B.*
Pecten comatus, Sow.
,, augulatus, ,,
,, demissus, ,, *B.*
,, paradoxus, Munst.
Ostrea gigantea, Sow. *L.*
,, sandalina, Munst. *B.*

Nota.—The fossils marked *L* belong to middle lias; those marked *B* to strata superior to oolitic limonite; the others are, for the most part, proper to upper lias, or to the stage of psammite and oolitic limonite.

APPENDIX II.

EXPLANATION OF THE SECTIONS (FROM BOTTOM TO TOP).

No. 1. Ottange.

3·50 m. to 4·00 m. grey and green ore.
5·00 m. alternate sterile beds and beds of yellow ore, yielding about one-third of ore.
12 m. to 15 m. sterile rocks.
3 m. to 3·50 m. silicious red ore.

No. 2. Kayl.

2·50 m. grey ore, unworked.
10 m. to 12 m. sterile rocks.
1·30 m. rich red ore.
2·50 m. ferruginous psammite.
0·50 m. red ore.
2·00 m. calcareous beds, with small beds of ore.
0·70 m. red ore.
3·00 m. sterile.
0·50 m. silicious red ore.

No. 3. Kayl.

2·50 m. grey ore, unworked.
10 m. to 12 m. sterile rocks.
3 m. to 3·50 m. rich red ore.
2·00 m. sterile rocks.
0·70 m. red ore.

No. 4. Esch (Galgenberg).

2·50 m. grey ore.
7 m. to 8 m. sterile rocks.
3·90 m. rich red ore.
2·00 m. sterile rocks.
1·00 m. red ore.
2·00 m. sterile rocks.
0·90 m. silicious red ore.

No. 5. Esch.

3 m. to 3·50 m. grey ore.
6 m. to 7 m. sterile rocks.
1 m. poor red ore.
1·60 m. psammite.
3·20 m. red ore.
6 m. to 7 m. sterile rocks.
1 m. red ore.
1 m. sterile rocks.
1 m. silicious ore.

No. 6. Belvaux.

2·50 m. black ore with blue nodules.
0·50 m. sterile bed.

8·40 m. {
1·00 m. red ore.
0·80 m. argillaceous ore.
0·50 m. green ore.
1·60 m. ore with hematite partitions.
2·70 m. grey ore.
1·80 m. red ore.

No. 7. Belvaux.

3·50 m. friable ore, named fine ore,
1·80 m. sterile.
3·00 m. grey ore.
1·00 m. red ore.
0·60 m. sterile bed.
1·00 m. brown ore.
3·00 m. poor brown ore.

No. 8. Differdange.

2·00 m. black ore with blue nodules.
2·30 m. sterile.
3·35 m. brown ore partitioned.
1·10 m. sterile.
5·00 m. grey ore.
1·70 m. sterile.
5·00 m. red ore with beds of ferruginous limestone, yielding one-third of ore.
1·60 m. sterile.
2·00 m. poor red ore.

No. 8. Niederkorn.

1·20 m. ore partitioned.
0·50 m. sterile bed.
1·75 m. ore partitioned.
5·00 m. grey ore.
1·50 m. sterile.
4·50 m. red ore with beds of limestone, yielding about 2-fifths of ore.

No. 8. Niederkorn.—*Continued.*

3·00 m. sterile.

3·00 m. black ore with rich limestone, yielding one-third of ore.

No. 9. La Madelaine (Titus Berg.)

5·00 m. grey ore, named fine ore.

3·80 m. sterile rocks.

1·30 m. red ore.

No. 10. Klopp (Rodange.)

4 m. to 6·00 m. grey ore (fine ore).

3 m. to 3·50 m. sterile slaty rocks.

0·50 m. to 1·00 m. red ore.

0·70 m. sterile.

5 m. to 7·50 m. black ore with rich limestone.

No. 11, Bois du Chat (Longwy.)

2·30 m. fine grey ore.

1·80 m. sterile.

3·50 m. yellow, grey, bluish ore and calcareous beds.

0·80 m. sterile.

1·30 m. red ore.

0·50 m. sterile bed.

3 m. to 3·50 m. red ore with limestone.

No. 12. Mont St. Martin.

1·50 m. to 2·00 m. poor grey ore.

2·50 m. to 3·00 m. grey ore worked by underground galleries.

0·70 m. shelly bed.

3·00 m. red ore with limestone.

No. 13. Halanzy (Belgium.)

4·00 m. brown ore with sterile beds.

2·50 m. ferruginous psammite.

No. 14. Musson (Belgium.)

1·60 m. to 2·00 m. rich brown ore.

0·80 m. sterile bed.

0·30 m. brown ore.

APPENDIX III.

ANALYSES.

	Ottange.				Kayl.	Esch.	
	Grey.	Grey.	Green.	Silicious Red.	Red.	Red.	Red Ore.
Volatile Matter	21·10	11·10	15·60	10·50	6·32	18·60	17·55
Insoluble „	16·05	18·30	22·40	37·60	9·87	23·55	7·80
Sesquioxide of Iron	48·30	52·70	57·20	51·00	61·26	49·25	58·15
Protoxide of Iron	—	4·90	—	—	—	0·75	—
Lime	15·70	9·95	4·00	1·00	14·82	12·00	7·60
Magnesia	trace	0·80	—	—	1·77	1·20	—
Alumina	4·75	4·80	—	—	4·73	5·75	8·00
Phosphoric Acid	—	—	—	—	1·23	0·72	—
Sulphur	—	—	—	—	trace	0·02	—
Oxide of Manganese ($Mn^3 O^4$)	—	—	—	—	trace	0·70	—
Iron	33·80	40·70	40·00	35·70	42·88	35·25	40·70

	Belvaux.				Differdange.			
	Green.	Grey.	Red.	Brown.	Partitioned.	Grey.	Red Ore.	Limestone.
Volatile Matter	15·00	15·60	18·50	25·00	—	15·87	16·11	—
Insoluble „	24·40	11·20	10·20	16·50	17·40	18·58	14·53	9·50
Sesquioxide of Iron	47·75	61·50	47·00	30·65	59·26	51·63	56·59	37·14
Protoxide of Iron	—	—	—	—	—	—	—	—
Lime	2·70	1·70	13·00	21·00	3·20	2·23	2·86	20·10
Magnesia	—	—	—	—	—	—	—	—
Alumina } Phosphoric Acid }	10·25	8·40	11·00	6·35	7·80	11·43	10·21	6·40
					—			—
Sulphur	0·03	0·02	0·03	—	—	—	—	—
Oxide of Manganese ($Mn^3 O^4$)	0·40	0·80	1·29	—	—	—	—	—
Iron	33·43	43·05	32·90	21·46	41·50	36·14	39·61	26·00

	Niederkorn.				La Madelaine.	Klopp.		
	Partitioned.	Grey.	Red Ore.	Limestone.	Grey Fine.	Grey Fine.	Black Ore.	Limestone.
Volatile Matter	17·00	15·80	17·16	27·03	16·35	18·00	12·92	27·50
Insoluble „	15·18	21·54	10·76	7·85	15·65	16·50	16·92	6·25
Sesquioxide of Iron	59·67	50·30	59·28	34·93	53·50	51·00	57·85	35·02
Protoxide of Iron	—	—	—	—	—	3·00	—	—
Lime	1·02	2·50	4·95	23·74	7·25	10·25	4·27	26·63
Magnesia	—	—	—	—	1·00	0·65	0·48	0·32
Alumina	5·93	8·09	5·76	} 6·33	5·25	5·00	5·96	2·95
Phosphoric Acid	1·21	1·36	1·87	}	0·78	0·70	1·25	1·25
Sulphur	—	—	—	—	0·03	0·02	0·15	0·11
Oxide of Manganese ($Mn^3 O^4$)	—	—	—	—	0·50	0·75	trace	—
Iron	41·77	35·21	41·50	24·15	37·50	38·00	40·50	31·51

	Mont St. Martin.	Halanzy.	
Volatile Matter	16·90	23·25	18·10
Insoluble „	21·35	3·25	10·00
Sesquioxide of Iron	46·90	56·50	53·25
Protoxide of Iron	—	—	—
Lime	8·90	12·25	3·90
Magnesia	trace	—	—
Alumina	5·70	8·00	—
Phosphoric Acid	—	—	—
Sulphur	—	—	—
Oxide of Manganese ($Mn^3 O^4$)	—	—	—
Iron	32·85	39·50	37·25

APPENDIX IV.

BLAST FURNACES OF LUXEMBURG AND LORRAINE.

(Situated near the iron deposit.)

1st GROUP OF NANCY (FRANCE).

	Working.	Standing.
Pont a Mousson (Haldy, Rœchling & Co.)	3	1
Frouard (Company of Montataire)	2	0
Liverdun (Company of Liverdun)	2	0
Champigneulles (Karcher and Westermann)	1	1
Maxéville (Vezin-Aulnoye Company)	2	0
Nancy (Steinbach Brothers)	1	0
Chavigny Do.	1	0
Jarville (Company of the Mines and Iron Works of North and East of France)	1	1 building.
	13	3

2nd. GROUP OF METZ-THIONVILLE (ALSACE-LORRAINE).

	Working.	Standing.
Novéant (Company of Novéant)	2	0
Ars-sur-Moselle (Karcher and Westermann	2	0
Ars-sur-Moselle (Iron Works of Lorraine)	8	1
Moyeuvre (Les petits fils de F. de Wendel)	4	0
Hayange Do.	5	1
Audun-le-Tige (Lejeune and Co.)	1	0
Ottange (Jahiet, Gorand, Lamotte and Co.)	4	0
	26	2

3RD. GROUP OF LUXEMBURG.

Esch-sur-l'Azette (Luxemburg Iron Works)	2	0	
Esch-sur-Alzette (Metz & Co. and Burbach Company)	4	0	
Dommeldange (Metz and Co.)	4	0	
Eich (Metz and Co.)	2	0	
Hollerich (Servais Brothers)	3	0	
Colmar-Berg (Servais, Majerus, and Co.) ...	1	0	
La Sauvage (Raty and Co.)	1	0	
Steinfort (Collard Brothers)...	2	0	
Rodange (Company of Rodange)	0	2	building.
Rumelange (Company of Rumelange) ...	0	1	do.
	19	3	

4TH. GROUP OF LONGWY (FRANCE)

Mont St. Martin (Baron d'Adelsward) ...	3	0	
Do. (Labbé)	3	1	
Gorcy (Labbé)	2	0	
Longwy-bas (Giraud and Co.)	2	0	
Senelle (D'Huart Brothers)...	1	0	
Rehon (Providence)	2	1	
Moulaine (Bassins houillers du Hainaut) ...	0	2	
Saulnes (Company of Saulnes)	0	1	building.
Villerupt (Iron Works of Villerupt & St. Claire)	2	1	do.
	15	6	

5TH. GROUP OF ATHUS (BELGIUM).

Iron Works of Athus	0	2	building.

APPENDIX V.

CONCESSIONS GRANTED IN FRANCE AND ALSACE-LORRAINE.

1st Group of Nancy (France).

No.	Names of the Concessions.	Dates.	Area in Hectares.	Names of the Owners.
1	Champigneulles	August 3, 1848	427	Karcher & Westermann.
2	Chavigny	June 16, 1856	372	Steinbach Brothers.
3	Marbache	Jan. 16, 1858	588	Haldy, Rœchling & Co.
4	Frouard	March 10, „	741	Company of Montataire.
5	Bouxières-aux-Dames ...	August 16, 1859	322	Do. do.
6	La Voiletriche	Sept. 26, „	341	Salin & Co.
7	Pompey	Feb. 2, 1860	127	Company of Montataire.
8	Liverdun	March 17, „	421	Poricelli & Co.
9	Hazotte	April 28, „	414	Vivenot & Co.
10	L' Avant-Garde	March 23, 1863	277	Company of Vezin-Aulnoye.
11	Buthegnémont	August 17, 1864	301	Company of Maubeuge.
12	Boudonville	„ 17, „	430	Do. of Vezin-Aulnoye.
13	Maxéville	„ 17, „	295	Company of Burbach.
14	Croisette-Liverdun ...	July 21, 1866	372	Do. of Liverdun.
15	Vandœuvre	Jan. 9, 1867	176	Lasson & Co.
16	Houdemont	„ 9, „	241	Company of Mines and Iron Works of North and East.
17	Custines	August 16, „	201	Haldy, Rœchling & Co.
18	Laxou	„ 30, „	266	Do. Dietrich.
19	Lay St. Christophe ...	Dec. 21, „	200	Cottreau.
20	St. Geneviève	March 14, 1868	195	Latron.
21	Le Foud de Monvaux ...	Feb. 10, 1869	286	Viellard-Migeon.
22	Le Grande-Goutte ...	„ 10, „	239	Bradfer.
23	Le Bois du Four	June 26, „	162	Jamin & Co.
24	Le Montet	August 4, „	366	Stumm.
25	La Fontaine des Roches...	„ 9, 1870	186	Simon, Lemut & Co.
26	St. Jean	Feb. 26, 1872	121	André.
27	Malzéville...	April 29, „	282	Colas Brothers.

2nd Group of Longwy (France).

No.	Names of the Concessions.	Dates.	Area in Hectares.	Names of the Owners.
1	Coulmy	July 26, 1844	62·	Gérard Brothers.
2	Chatelet	Nov. 9, „	5·80	Boutmy.
3	Romain	August 9, 1848	140·	Labbé.
4	Warnimont	July 24, 1857	114·50	De Ludres.
5	Senelle	Feb. 24, 1864	208·	Boutmy.
6	Mont St. Martin.. ..	Sept. 17, „	576·	Labbé and Baron d'Adelsward.
7	Mexy	Feb. 7, 1866	230·	Giraud and Co.
8	Saulnes	August 14, 1867	469·	Company of la Providence.
9	Lexy	Dec. 21, „	90·	Berger and Thomas.
10	Pulventeux	„ 21, „	216·	Marquis de Lambertye.
11	Moulaine	Feb. 1, 1868	371·	Philippart.
12	Bois du Chat	Sept. 2, „	221·	Mineur and Co.
13	Rehon	May 1, 1869	343·	Company of Maubeuge.
14	Herserange	July 13, 1870	433·	Baron d'Adelsward.
15	Villerupt	Feb. 25, 1873	159·	Iron Works of Villerupt and St. Claire.
16	Longlaville	June 25, „	261·	Company of Saulnes.

3rd Group of Metz-Thionville (Alsace-Lorraine).

A.—Concessions granted by the French Government.

No.	Names of the Concessions.	Dates.	Area in Hectares.	Names of the Owners.
1	Hayange	July 18, 1834	—	Les petits fils de F, de Wendel.
2	Moyeuvre...	„ 18, „	—	Do. do.
3	Ottange	1847	554·	Jahiet, Gorand, Lamotte and Co.
4	Rosselange	1848	116·	Iron Works of Lorraine.
5	Lacharbonnière et Varraines	„	580·	Do. do.
6	Vaux	July 18, 1853	130·	Schlinker and Co.
7	Novéant	Dec. 20, 1854	300·	Company of Novéant.
8	Arry	August 16, 1859	461·	De Fréhaut.
9	Marange	Dec. 19, 1860	637·	Pougnet.
10	Hayange and extension...	March 7, 1863	1957·	Les petits fils de F. de Wendel.
11	Moyeuvre „	„ 7, „	2302·	Do. do.
12	Neufchef	Sept. 22, 1869	562·	Do. do.
13	Tillots	„ 22, „	513·	Do. do.

C.—CONCESSIONS GRANTED BY THE GERMAN EMPIRE UP TO 1ST AUGUST, 1873.

No.	Names of the Concessions.	Dates.		Area in Hectares.	Names of the Owners.
1	Mance Gorgimon ...	April	1, 1872	421	Karcher & Westermann.
2	Châtel	Dec.	18, „	234	Stumm Brothers.
3	St. Quentin	„	18, „	302	Böcking Brothers
4	Rozerieulles	„	31, „	232	Iron Works of Lorraine.
5	Gravelotte	Jan.	18, 1873	225	Dillingen Iron Works.
6	Norroy	„	18, „	230	Schœnau Iron Works.
7	Rombas	„	25, „	215	Funcke and Elbers.
8	Moyeuvre La Grande ..	„	28, „	250	Cosack and Co.
9	Saulny	Feb.	15, „	267	M. Pougnet.
10	Orne	„	18, „	215	Company of Novéant.
11	Lorraine	„	18, „	207	Stumm Brothers.
12	St. Paul	March	19, „	219	Später, Wirth and Co.
13	Audun-le-Tige	April	15, „	228	A. Krämer.
14	Tincry	„	30, „	231	Diefenbach and Co.
15	Mance extension.. ..	„	30, „	242	Karcher & Westermann.
16	Burbach	June	9, „	226	Burbach Iron Works.
17	Marengo	„	9, „	220	Ferdinand Remy & Co.
18	Wilhelm	„	19, „	219	Sommer, Bloser & Co.
19	Fontoy	„	24, „	203	Gabriel & Bergenthal.
20	Kanfen	July	14, „	186	Friedrich Wilhelm Iron Works, in Mulheim.
21	Redange	„	20, „	88	Stumm Brothers
22	Heyett	„	20, „	42	Metz and Co.
23	Butte	„	20, „	128	Villerupt and St. Claire Iron Works.
24	Glückauf	„	20, „	147	Funcke, Berger, and Phœnix.
25	St. Michel	„	21, „	186	Bauret, Lejeune & Co.
26	Arsweiler	„	26, „	210	A. Krämer.
27	Witten	„	28, „	194	Steinhausen Iron Works.
28	Œtringen	„	28, „	288	Dillingen Iron Works.
29	Pensbrunnen	„	28, „	212	Otto Meurer.
30	Marspich	„	30, „	343	C. de Beulwitz.

The President remarked that, to those members of the Iron and Steel Institute who were connected with the Cleveland iron trade, the paper they had just heard must be one of very great interest, inasmuch as the ironstone described by the author was—geologically speaking—analogous with that of their own country. M. Habets had pointed out very clearly two distinctive characteristics of those beds of ironstone, which would be found, more or less, to resemble in detail that of their own country, viz., the existence of two separate beds of ironstone, of which the upper seam—like that of Cleveland—appeared to be of a very variable character, both as regards its chemical constitution and physical character generally; whereas, the lower bed—also like the Cleveland stone—was much more uniform, both in extent and in chemical composition.

The thanks of the meeting having been given to M. Habets, the President said that, before they proceeded with the next paper, he had to introduce to them Mr. Raymond, from the United States, the President of the Institute of Mining Engineers of that great country. He was the bearer, to the members of the Iron and Steel Institute, of an invitation to visit the United States; indeed, he believed he was stating what was strictly correct, when he mentioned that that invitation was mainly due to the interest which had been taken by Mr. Raymond himself, in connection with their contemplated visit to the great iron-making district of the Western world. Mr. Raymond would kindly communicate to the members themselves the terms of the invitation, and he, therefore, begged to introduce that gentleman to them.

Mr. R. W. Raymond said that, as their distinguished President had just informed them, he stood before them that day as the representative of the American Institute of Mining Engineers, in order to tender to them a very cordial invitation on the part of that Institute to hold one of their meetings, in 1874, within the boundaries of the United States. That invitation had been formally voted by their Institute, at its meeting in Philadelphia, and had been formally transmitted to their Secretary, and acknowledged by him in a letter to their own Secretary in the United States. It, therefore, only remained for him to tell them, in a word or two, to what they invited them, and to mention one or two things which he hoped would make the cordial acceptance of the invitation a matter of pleasure to them as well as to their own people.

The American Institute was not a very old body—not so old as their own Institute; but they had a large number of members, comprising the active men in all branches of the mineral industry of their country. They were, however, more largely represented among the coal and iron and steel men than in other branches, since their Institute took its rise in the eastern part of the country, where those industries were very wide-spread and important. As they were aware, they had a good many societies for iron and steel in the United States, but they were all more or less tinted with questions of political economy. Now, the American Institute of Mining Engineers had nothing to do with questions of political economy. They did not trouble themselves with those questions; they recognised the fact that, above and beyond all such temporary expedients as politicians or statesmen might devise, and concerning which national economists might continue to be at difference, a people who knew how to do a thing would always do it. In Liége, and in every country, and in every branch of industry, the nation or individual that knew how to do, was master of the situation; therefore, in his country, and in theirs, it was a question of science fundamentally, and ultimately of skill: in other words, of brain and study—of interchange of ideas—upon which the whole success and prosperity of every industry rested. Therefore, they in America represented a base, he thought, upon which they could cordially go to them, because they were not a society engaged, on the one hand, in fighting their interests, while on the other hand they invited them as their guests. They were a society engaged in the same work as themselves; they were an institute in favour of the interchange of mutual experience to advance the arts to which they had devoted their lives—the art of mining, and the art of metallurgy. So much for those who invited them; they were very certain of being able, on their part—if the Institute should find it practicable to accept the invitation—to give them a pleasant time. They knew they could show them something that would interest them. He need not tell them how much they were indebted to England and to Belgium (for he included Belgian engineers in his remarks)—to both those countries—for the progress of ideas, particularly those relating to the manufacture of iron and steel; at the same time, he hoped that they in America would be able to show anyone who did them the honour to visit them, that they had not been stupid or unprogres-

sive scholars, and that they could, in some respects, throw light on some questions that—for some reason or other—seemed to be moot questions on this side of the water. He thought they could show them, if they did them the honour to visit them, Bessemer works producing more steel, in proportion to the plant, per day, than any works in the world. He thought they could show them three-high rolls running, all over the country, with great success and ease, without any trouble of shock, or reverse, or break of section; he thought they could show them a great many things done, simply because they did not know enough to let them alone; done, because they shut their eyes, and went at them and did them; and they afterwards found out, by discussion and enquiry, that they had been considered difficult to do; so that even in those arts, while the English manufacturers deservedly took the lead in the world, they might be able to give them interesting and profitable matter for contemplation; at the same time, they wanted them to go to America, not because they (the Americans) would do them good, but because they hoped to get great pleasure, great benefit, and profit, from their visit; they could only promise them, in return, that they would make it as interesting and entertaining for them as the resources of their country (which they were told were somewhat extensive) would enable them to do. They would permit him to say that his own field, practically, was not so much iron and steel (as his field geographically was not so much the eastern part of the country, which they would be most likely to see) as gold and silver, lead and copper, and the western part of the country; but he would promise them most heartily that, if any of them had time and strength, after enduring the hospitality of the East, to follow him into his field in the West, then he would show them something that would open their eyes. He would be very glad to take them with him, in Colorado for instance, to show them the rapid expansion they had given there to the invention of narrow gauge railways; an invention which took its rise on the English side, but which had been applied more extensively on theirs; he would like to show them, *apropos* of the paper, in the last number of their JOURNAL, and which had been read at their last meeting, on transmission by wire railways, the wire railways which conduct their ores and workmen up the sides of otherwise inaccessible mountains, 13,000 feet above

the sea level, and within the line of eternal frost and snow on the Rocky Mountains; he would like to show them the railway that climbed the steep Sierra, and the water works in the White Pine Desert, that raise water 900 feet, and carry it to another mountain across a valley to reach a little mining village; he would like also to show them some of their natural wonders. The Yosemite Valley, which was certainly a "big thing," and the Geysers of the Yellowstone, of which he had the pleasure to be among the early explorers. Without indulging any further in that characteristically American style, he did most earnestly hope that they would find it consistent with their interests and engagements to go to America next year. Their Council (of which he was President) had full authority from their Institute to act in concert with the English Institute to arrange all particulars as to time and place, so as to suit their convenience. His own ideas—gathered from correspondence and conversation with leading members of the iron and steel industries at home—led him to suppose that some such point as Pittsburg or Philadelphia—as far inland as Philadelphia—would be selected for the place of meeting. They only hoped and trusted that the English Institute would find it possible to join them in meeting on the other side of the water to give them the benefit of their presence, and enable them to show them all they could in the way of instruction and hospitality.

The President said, if there had existed the slightest vestige of doubt in the minds of any members as to the genuineness of the offer made to them by their American brethren, that doubt must have been completely dispelled by the very eloquent terms in which Mr. Raymond had conveyed the invitation to the meeting. It would be impossible, of course, on that day, to decide the question, but it would be referred to the Council, and, during the week, they would be able to convey to Mr. Raymond some appropriate and definite answer to the very kind invitation of which he was the bearer.

The President then called on M. Buttgenbach to read his paper.

BUTTGENBACH'S SYSTEM OF CONSTRUCTING BLAST FURNACES.

By FRANZ BUTTGENBACH, Neusser Hutte, Prussia.

Having been requested by the Iron and Steel Institute, of which I have the honour to be a member, to prepare a report upon the Blast Furnace System, known as the Buttgenbach System, for the meeting to be held at Liége, in August, 1873, I have now the honour of sending the following description:—

In 1859, I undertook the management of the Neuss Smelting Works, situate on the Lower Rhine, Rhenish Province, and there I found a high blast furnace, then just recently erected, which had not yet been in active operation.

An engineer, late of the Siegen district, who had seen all the blast furnaces of that part of the country set up against steep hills, supplied with raw materials brought up to the required level by means of carts and wheelbarrows, and having steam boilers and air-heating apparatus mostly on a level with the furnace mouth, when charged with the duty of sketching out a plan for the work above mentioned, in his inability to free himself from the influence of this (old-fashioned) notion, actually projected and caused to be built on a level plane, a stack of masonry measuring 40 feet square at its base, by 40 feet in height, rising perpendicularly.

At the centre of this stack was placed the blast furnace, its hearth being accessible only by means of very narrow embrasures; upon the platform of the furnace mouth two steam boilers have been erected, as well as a draught flue, the idea being, probably, that the descent was to take place contrary to the natural tendency of the gases.

This stack being altogether too bulky for me to attempt to remove it bodily, I simply contented myself with clearing away as much of

it as possible round about the hearth, and in such condition as I then brought it to, our blast furnace has been continuously at work ever since 1860, under my management. The difficulty of working with a furnace similarly blocked in, but more especially the fact resulting from the experiences of two or three years operations that the fire-proof facings had completely worn away, impelled me to attempt the construction of a blast furnace, the heart of which should be readily accessible on all sides, and following up this idea, I built up at our works a blast furnace 50 feet high and 17 feet in diameter at the boshes.

In justice to my brother, a metallurgical engineer, I must not here omit to state that, in elaborating and finally determining upon my plans, I had the advantage of his suggestions and valuable advice.

In 1867, a model of the above-named blast furnace was exhibited in Paris, and I had the satisfaction, not only of being complimented upon my idea by a great number of engineers of every nationality, qualified to express an opinion on the subject, but of having conferred upon me, likewise, the distinction of an honourable mention on the part of the Jury of the Exhibition. The articles contributed to the *Revue Industrielle* of the Exhibition of 1867, by Professor Jordan, who occupied the Chair of Metallurgy at the *Ecole Centrale* in Paris, have brought my system into notice in France. Since 1867, six French ironmasters have adopted my system, and have constructed nine blast furnaces from my plans and in accordance with my suggestions. Both in Germany and Austria my system has likewise been introduced with success at several ironworks.

The fundamental idea of this mode of construction, and the advantages of the system may be summed up as follows, viz. :—

1st. The mason work of the stack is quite independent of the blast furnace proper. Each ring or course of bricks constituting the hearth, boshes, and inside wall, is readily accessible and free from any casing, except as regards a small portion, measuring from 3 to 4 feet in height, at the widest section of the blast furnace.

Consequently, the whole of the above several parts are completely bare and easily reached for any purpose required, even while the furnace is in active operation. This feature conduces to

the duration of the furnace, for in case of need any injured part can be repaired, even when the furnace is at work.

2nd. The inside wall and the upper part of the boshes being cooled by the atmosphere having access thereto, they remain in their normal condition without wear, and do not become unduly heated at any time, being, therefore, indefinitely kept in a state of preservation, since there never occurs a fusion of materials at this height.

3rd. The hearth, and the lower portions of the boshes, being apt to suffer after a certain time from the destructive action of the materials in a melting state, may be replaced without any difficulty whatever while the work is going on, so that there is no occasion to apprehend any extinction of the fires so long as the in-wall is not destroyed. If putting out the fires should at any time become necessary, the hearth and the boshes could be renewed without affecting the in-wall injuriously.

4th. Each particular brick being accessible during the working of the furnace, and the progress of the fire easily ascertained, corrosions can be obviated by cooling down with water thrown on the several parts, or by means of water vessels or tuyeres wherein the water circulates placed within these parts as far as the inside of the furnace, whereby the wear and tear can be checked.

5th. The utilization of the gas at the furnace mouth can be so managed as to make it yield the best results. The pillars supporting the platform of the furnace top are gas pipes, and drop into sheet iron vessels fixed to the summit of the base of the stack where it slopes away. These vessels are open on one side, so that when filled with water up to a certain height, they can be shut down by means of a valve, measuring a few metres square. The gas issuing forth out of the furnace mouth finds its way into these receptacles, and in its passage through them travels over a large surface of water. Here it deposits the dust, while a great part of the water suspended in the gas, in a state of vapour, is condensed. Consequently, the gas reaches its destination in a highly purified condition, and may yield the very best results in those parts where it is desired to make use of it.

The arrangement of the said water receptacles allows of the withdrawal of the dust or grit, deposited while in full working, and in the event of an explosion, the area of from five to six centimetres of

the water column paralyses, as though it were a gigantic valve, any injurious effects. In point of fact, instead of dreading, we rather wish for explosions from time to time, since they serve the purpose of clearing off the dust and grit that may still be clinging to the inner walls of the pipes. Moreover, there is the advantage of confining these subsidiary appliances to a spot on the works, which does not in any way interfere with the general progress of the manufacture.

6th. The gas pipes being supporters also of the platform surrounding the furnace mouth or top, render the said platform independent of the blast furnace proper, and that without involving any special outlay.

In the first days of this erection, critics expressed a fear that the chilling of the parts thus exposed in this blast furnace would be achieved only at the cost of a greater consumption of fuel. But, contrary to such apprehensions, experience has amply shown that blast furnaces, the brick work of which at the core is in direct contact with the outer air, use less fuel than do those that are protected by strong mason work, or shut in by means of a second inner casing with a lining of sheet iron; and the opinion expressed by me from the very beginning explains this result. For, in point of fact, a blast furnace should form at its lower part a smelting crucible, and it is generally known that every expedient available is brought into use for the purpose of cooling the walls of this portion of the structure. The boshes are a kind of retort wherein the ore is reduced by means of its contact with the fuel, and the in-wall is like unto the neck of a retort, and in which the ore is prepared by the action of a moderate heat and contact with the reducing gases.

If the ore sinking into the in-wall section acquires a spongy condition, and continues in this condition without undergoing semifusion, it is quite obvious that the effect produced by the gas must be infinitely greater, and that the ore must descend into the zones of the boshes and of the hearth in a much better state of preparation than if the heat of the in-wall had partially converted it into cinder, so that the reducing gas must pass on, incapable of action upon such ore, except superficially. The ore thus brought into a better state of preparation, must of necessity require less fuel in order to its perfect fusion.

Moreover, in the event of cinder being formed at the in-wall zone, it will adhere to the walls and produce concretions, which always impede the proper working of a blast furnace. When the ore sinks with regularity the smelting process is facilitated, whereby a further saving of fuel is effected.

The truth of the foregoing assertions has been fully established by the experience of eight years' working at our works. Concretions have never been noticed, and the proportion of fuel required for the furnace, constructed upon the new principle, has always been from 10 to 15 per cent. smaller, *cæteris paribus*.

When good coke has been used, excellent No. 1 foundry pigs have been produced from ores yielding 35 per cent., the consumption of coke being in the ratio of 11 parts to 10 parts of pig, at a temperature of 350 deg. centigrade, under blast, while in the case of white pig it is one part less of good coke to every part of pig. Touching the fears entertained of undue chilling in severe seasons, the following facts have served to dispel them *in toto*:—

The blast furnace at the Neuss Works has more than once been suddenly blown out for several weeks, owing to causes quite foreign to its working capabilities. Three of these suspensions occurred during the war in the year 1870-1871, owing to the want of fuel, and no preparatory arrangements were made before any of the said suspensions of work. They lasted during a space ranging between three and ten weeks respectively.

I did not touch the blast furnace during any of the periods of stoppage referred to, the most prolonged of them occurring at a time when the thermometer registered 10 to 17 deg. C., and yet when work was resumed the furnace did its work again with surprising regularity. On the last occasion, however, I was obliged to raise up the tuyeres, in consequence of the thickening of the bottom stone.

For the last two years, the furnace has been blown from one metre and fifty centimetres above the original level. It behaves admirably, producing as much as 50,000 kilogs. in 24 hours. I cannot conceive of any blast furnace constructed upon a different principle being capable of withstanding the effect of events such as those detailed above, and yet remaining fit for work. The blast furnace I am describing has entered upon the eighth year of its existence, and the condition of its core is such, as yet, that one will readily

admit the almost certainty of its lasting out double or three times the said number of years, considering that the bricks of the in-wall and of the boshes have, up to the present, lost nothing of their thickness. This may be easily verified, for all the bricks coming to the outer air may be examined at any moment. Their thickness may be unerringly ascertained by piercing the walls with a small pin drill. The walls, be it borne in mind, are but weak, measuring no more than 2 feet thickness at the base, and 18 inches at the summit of the in-wall.

This thickness they have not lost during an existence of eight years. Experience has shown, moreover, that, the core of the furnace being exposed to the air, the internal heat produces hardly any effect upon the bricks, either by dilation or contraction. Hearth, boshes, and in-wall were originally fastened together in the Neuss Blast Furnace by means of flat iron binders occurring at the third course alternately.

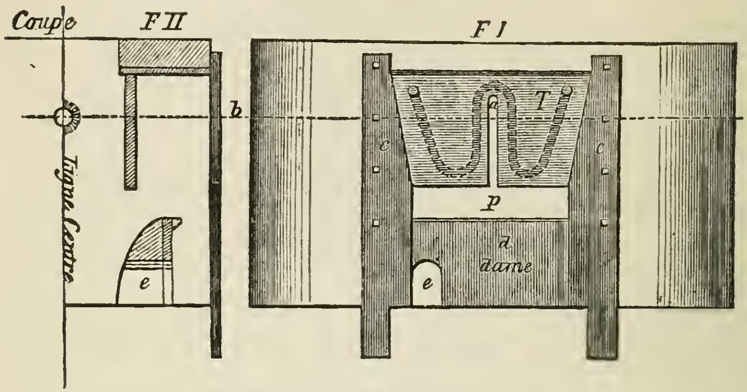
This precautionary measure appears superfluous. It is over four years ago since I have had the binders removed at the hearth and boshes, as well as at the in-wall, in part; for I perceived that they served no useful purpose, since the cooling down of the bricks prevents expansion altogether. Indeed, the furnace in the parts referred to is just the same as on the day of its erection.

At Vienna, I have exhibited at the *Deutscher Pavillon für Bergbau, Hüttenwesen* (No. 8635) a model of this blast furnace, in which I have shown the deductions made from an experience of the working, during a period of eight years, of the first blast furnace of its kind.

The chief alterations introduced by way of improvement consist in a diminution of the stack to a very great extent, at that part of it which supports the in-wall; this diminution being accompanied, however, by so considerable a sloping away from the centre towards the rise of the boshes, that the space around the hearth and the boshes has been still further enlarged, so that it may be considered as perfectly isolated.

I have also introduced a peculiar description of closed hearth, which admits of ordinary working, as well as working with a closed hearth. I have been using this method for the last six years with the very best results. Its application is very simple indeed, and free from the objectionable features of other known methods, since

the work of the bottom of the furnace can be performed, in case of need, without depending upon the mouth of a tuyere for running off the slag.



The hearth is closed in by a cast iron tymp placed in the usual position. This tymp arch is cooled by a current of water passing through a coiled iron pipe fixed in the cast iron.

In the centre of this plate there is an aperture or orifice measuring ⅜ of an inch running almost over the entire height, and the cooling pipes are situate as near this kind of slit as may be. This slit is closed up by means of ordinary clay. *A*, the upper portion of the slit, is placed two or three inches higher than the centre of the line of the tuyeres.

FRONT VIEW.

b, level centre of the tuyeres; *c*, columns of the breast; *d*, dam; *e*, tap hole; *p*, space between dam-stone; tymp closed in with clay; T, cast iron tymp.

The slag of the blast furnace ascending above the dam-stone and reaching the level of the tuyeres runs off easily through a hole driven by means of a light steel bar into the said slit; and, since the level of this hole may be altered at will, a means is thus afforded for changing the level at which the slag is run off over a range of 24 inches, which is a very great advantage in itself; but, in addition to that, there is this further facility, namely, that nothing hinders one from tapping the melted ore at this same slit.

I shall not dwell at length upon the advantages of such an arrangement, but will simply state that during the six years, since I have been making use of it, I have been unable to find any fault with it, and that in my practice it has always possessed all the advantages of the closed breast.

In the said model, I have also applied three rows of tuyeres made of gun metal overlying one another, in such wise, that the upper row is 2½ metres above the first.

These tuyeres reach into the interior of the blast furnace as deeply as the blast tuyeres. By means of this plan, the walls of the hearth are kept in perfect preservation, and in case of accidents, the blast may be introduced through the said tuyeres, which affords advantages that ironmasters will be able to appreciate without any further explanation of mine.

Practice has shown that this kind of blast furnace, being readily accessible on all sides and at any moment, is far more easily managed than any other system; which fact, practical men will readily admit.

Over and above the advantages above enumerated, there is another, namely, that the construction of such a blast furnace must evidently be, and is, in point of fact, much less costly than that of any furnace built upon another principle. It takes much less time to build, to dry and to fire: in fact, it is a practical elucidation of your English proverb, "time is money".

Let me add, too, that there is nothing to prevent the application of my system to blast furnaces of all shapes and sizes, and that the largest section would just be the one best adapted for illustrating its great advantages, no less, speaking relatively, than its saving qualities.

In conclusion I must say, that, to my mind, this system is the most advanced in simplicity of blast furnace construction.

In the afternoon of the same day, the members visited various ironworks and collieries, particulars of which will be found in the general account of the Liége proceedings.

WEDNESDAY, 20TH AUGUST.

The President, in commencing the proceedings, said he would be very glad to hear the observations of any gentleman upon the subject of M. Buttgenbach's paper, which was the last taken on the previous day.

Mr. Edwin F. Jones would like to ask M. Buttgenbach a few questions. In the concluding part of his paper he said "Nothing hinders one from tapping the melted ore at this same slit." Did M. Buttgenbach mean metal when he referred to that slit? He (Mr. Jones) would also like to know the inclination of the sides of the furnace from the boshes upwards, and the difference between the diameter of the furnace at the bosh and the diameter at the top? He would also like to know what advantages were to be derived from the use of stone pillars instead of cast iron columns, as used in Cleveland for supporting the super-structure? M. Buttgenbach said he had taken away the hoops that were intended for the support of the hearth and body of the furnace. Now, their experience in Cleveland was that they could not do well without the support derived from those hoops; but there was this difference, as far as he could see: The furnace in question was only 50 feet in height, whereas in their district they had them double that height. There was also another thing which appeared to him (Mr. Jones) to be at all events the reason of their furnaces not bulging out, *i.e.*, the immense difference between the size of the furnace at the bosh and at the top, which was in itself sufficient to do away with lateral pressure of the material on the sides; there was more room for its falling down gradually on to the boshes, and thereby they did away in a great measure with the tendency to bulge out the furnace. He (Mr. Jones) thought that the reason why the furnace held together arose more from the difference in the size between the bosh and the top than from any other cause. The only apparent difference that he could see between M. Buttgenbach's and their own mode of construction seemed to be in the arrangement for taking off the gases, as to which he thought they might learn something.

Mr. Edward Williams understood M. Buttgenbach to say that the thickness of the brickwork sides of his furnace was uniformly two feet. He felt sure that for such furnaces as those in the North

of England such thin sides would not do. The furnaces contained about 35,000 cubic feet of material, and two feet walls, Mr. Williams thought, would not sustain the weight. M. Buttgenbach claimed, as an advantage, that his brickwork was easily got at, there being no casing interposing to prevent the replacement of any portion that might require replacing. The Cleveland furnaces, many of them, were uncased in the same way. The brickwork, as a rule, was about 4 ft. 6 in. thick, and even then it was thought necessary to hoop them, lest the sides might give way. The advantage of getting at the brickwork easily, which did not seem much of an advantage after all, applied to the Cleveland furnaces as well as to those of M. Buttgenbach. The stone pedestal he (Mr. Williams) considered very objectionable, and not so good an arrangement as the cast iron columns becoming so general in Cleveland. It was, to his mind, proved that columns were better in every way than either stone pedestals or those of brick. He did not think there was much in M. Buttgenbach's system which could, with advantage, be imitated in England.

Prof. Jordan said: Not being able to understand sufficiently well the discussion for entering into it, I will only try to communicate to the Institute, as required by Mr. President, and as simple matter of facts, the information I possess and the observations I have made on nine French blast furnaces built upon M. Buttgenbach's system. Two furnaces, sixty feet in height, have been constructed at the Marseilles Iron Works, with which I am well acquainted; they are built with cast iron pillars, and the stack is braced with iron hoops every two feet. One of them is working its fourth year. The system with naked lining without any casing of brickwork or metal has been adopted for quickness of construction and easiness of repairs. The tunnel-head platform is supported by small cast iron columns, the gases being used on a terrace behind the blast furnaces. One furnace is making spiegeleisen and the other manganesian No. 1 grey iron; the working is very hot, and the wear due to manganesian ores is very great. The system has been found to answer well, and the managers have been able to undertake repairs and to replace bricks in all parts of the lining, even a few feet under the tunnel-head opposite the charging bell, where the lining had been partially worn out by the impact of hard and heavy ores. The coke used per ton of iron is less than in the preceding furnaces,

but as these were only 47 feet in height, I am not prepared to attribute the saving to the system of construction. I can only say that I am perfectly sure the consumption of coke is not greater in Buttgenbach's furnaces than in other ones. Three other furnaces, with naked, but hooped, lining, have been working in Givor's ironworks for four or five years. One only of the three has a brick-work base. I know that the managers are well satisfied with them. Two furnaces, nearly similar to those in Marseilles, have been built in the Haute-Marne district, at Brousseval and Marnaval Iron Works. I have just received a letter from the proprietor of the former: He says that his furnace is working very well, making fine No. 1 grey pig, which is as grey as Scotch pigs. I know some persons are afraid of the leakage of the gases through the pores of brickwork. I have made observations and I have never been able to detect leakage of this sort. It has been said that, in consequence of this leakage and of the cooling by conduction, Buttgenbach's furnaces could not make No. 1 grey pig: we have just now in France four furnaces of this class making No. 1 iron. Besides, experiments made in Sweden by M. Wiman show that the loss of heat by conduction above the boshes is practically insignificant. It has been spoken, too, of the penetration of rain into the stack through the porosity of the fire-brick naked lining. I have seen, indeed, a furnace where this emergency had occurred. During 30 or 40 days of continual raining, the water had penetrated through two feet and more of fire-bricks on the side exposed to the wind. But that was due to the lining being new and not having been coated externally with coal tar pitch, as is necessary, in wet countries especially. It is very easy to prevent this inconvenience.

Mr. Thomas Whitwell, coming from a district making upwards of one million eight hundred thousand tons (1,800,000) per annum (as they were in Cleveland), desired to say a few words upon one or two points that had not yet been referred to with regard to that very ingenious blast furnace. In the furnaces to which the system had been applied, he thought they used the mine uncalcined, and the raw small mine was often highly charged with water. Now in Cleveland, they used calcined stone, and they had the gas going off from the top of the furnace at the temperature of from 300 to 400 degs. centigrade, instead of having it, as in the case of the furnaces to which M. Buttgenbach's system had been applied, at

140 degs. centigrade. The use of dry calcined mine caused the fire to mount much higher in the furnace than it otherwise would, consequently there was much more heat in the upper part of their Cleveland furnaces than was the case in furnaces in other parts of the country, in which they did not use calcined stone. He (Mr. Whitwell) had no doubt the system would work very well where raw small mine was employed, as it could be much better distributed, and in the same furnace a system of washing the gas had been introduced by passing it over water, as they saw, the previous day, for instance, at Ougrée. There was no doubt that the system of M. Buttgenbach answered very well for gases at a low temperature, and highly charged with vapour of water, but with gases of a high temperature, it was very much to be feared that, in place of condensing the steam in the gas—inasmuch as they in Cleveland had no steam in their gas, or next to none—they would make steam, and put it into the gas, and in that case he could not see that the system of M. Buttgenbach would be suitable for the works where they had calcined ironstone to deal with, and especially where that ironstone was often going into the furnace nearly red hot from the calcining kilns. With regard to economy, he (Mr. Whitwell) would also like to ask whether there was any economy in coke in regard to that special blast furnace? No doubt the system of distributing the materials in that country with a Trémie and the Prise de Gas Central, and levelling round, would give the best results, and was the very best system of charging they had so far seen, as they could always see the minerals, and he had no doubt whatever that that furnace would work—so far as distribution was concerned—as perfectly as any furnace could work; but it was chiefly on the points of the ironstone going into the furnace in a dry state—the fire rising very high in the furnace—and the action of large masses of ironstone sliding from the cone on to the sides of the furnace, that he (Mr. Whitwell) would like some further information, because they found that the large masses of ironstone coming from the calcining ovens in Cleveland, had an effect in corroding, or wearing away, the sides of the blast furnace, and the exceeding thinness of the masonry in M. Buttgenbach's furnace seemed ill suited to withstand this action.

M. Buttgenbach replied in French, and said that at first sight many objections might be brought forward against the system of blast

furnaces established at Neuss (Rhenish Prussia); but experience had shown that these objections could not be sustained. In lessening the thickness of the bricks, he had been influenced by the idea that they should prevent as much as possible the ores becoming half smelted at the height where they must be reduced by the gases. In fact, as he said in his notice, a blast furnace must form in the bottom part a melting crucible, and it was generally known that every means were used to cool the walls of that part as much as possible. The boshes formed a kind of crucible, in which the ores were reduced by their admixture with the fuel; the shaft was the part in which the ore was manipulated under the influence of a moderate heat, and the contact of the reducing gases of the blast furnace. It was well known that an ore which was in a pasty state and not scorified, was much more easily reduced by coming in contact with the gases. When the inner lining of blast furnaces was thickened by masonry, it was evident that the brick walls must get very much heated. It followed that the materials which were fastened to or run along the walls got more or less scorified. Anyone who had observed blown-out blast furnaces would have noticed that, after several years' use, the inner lining was nearly always scorified to the very top. The scorification was prevented by letting out a certain quantity of heat above the boshes, and keeping the ores in their pasty state. He believed that the inconvenience resulting from the loss of heat through the walls which were very thin was largely compensated for by the facility with which the unscorified ores were reduced. His opinion was justified by experience. There were at the establishment where this system was applied two blast furnaces. As he had said in the paper, the one was on the ordinary system, the other one belonged to the new. The former, working with the same charge, and on the same conditions as the latter, required constantly—this was proved by an experience of eight years—a much larger quantity of coke to produce good results. With the new system, the materials did not stick so easily to the walls. Now, it is known that the sticking to of materials sometimes produced scaffoldings. These masses, on getting loose, entered into the crucible, and led to difficulties in the midst of the best workings. For eight years, at Neuss, they had had no scaffoldings, although the blast furnace had been working under very unfavourable

conditions, as stated in the notice. The cooling did not produce any ill effect on the working of the blast furnace; this had been proved in several instances when the furnace had been stopped suddenly after being full on. It had been stopped, for instance, at a temperature of air 12° to 17° under zero, suddenly, without any preparation, and during ten weeks. The author had caused all the openings of the lower part to be closed. When the blast was again put on, excellent pig iron was made the same day, and the blast furnace had continued to work in a very satisfactory manner. This occurred several times during the same winter. He had simply had the tuyeres taken up, and for three years the blast blew through these raised tuyeres. The blast furnace produced the same quantity and quality of iron. This showed that it was advantageous to have superposed tuyeres, which prevented corrosion. Corrosion was further prevented by the water tuyeres, which entered into the interior of the blast furnace. A blast furnace which did not corrode at the boshes was seldom similarly affected at the tuyeres. He did not use these tuyeres at the outset, but only employed them later, and he had found them answer well. They had also been adopted in several other establishments, where they also gave great satisfaction. It might sometimes happen that the working of a blast furnace was stopped by difficulties of smelting. In such cases it commonly happened that the tuyere was blocked up by lumps which did not melt. Blast enough could not be applied to obviate this inconvenience, which was a sign of a beginning of bad working. Under such circumstances, the nozzles need only to be simply raised, and the blowing to be done through the second level of tuyeres. It took only twelve to twenty-four hours' work to melt down the lump which obstructed the lower tuyeres, and to put the furnace in good working order again. As to the objections which had been made in respect to the height of the furnaces, he might say that in France they had built higher stacks than those at Neuss, which were only 50 feet. Thus, at Marseilles there were some 50 feet in height. He did not see any reason why they should not be higher still, because the pressure of the materials in the blast furnaces did not exercise a great effect upon the walls. The heated lumps are more or less caking, and the lateral pressure did not so easily take place. He had seen even a large hole made in a furnace at the height of

the boshes; the materials which were at that height remained suspended; they held together without giving much lateral pressure. It had been stated that a thickness of 2 feet for the casing, and 18 inches for the top part, would not be sufficient for high blast furnaces. However, the blast furnace of Neuss, which was a specimen of this system, and had been working for eight years, had really these dimensions. It was working constantly, and it could be easily ascertained that the casing had not lost 2 centimetres over its whole height. This could soon be found out by boring through a brick. It often happened that in the top part of blast furnaces, openings were produced, and the flame came through the walls, which were from 10 to 20 feet thick. Such a blast furnace could be repaired only with very great difficulties, but accidents of this kind could never happen with blast furnaces of the system to which the speaker referred. The outside cooling was an obstacle thereto; but if it should happen, it was easily remedied. It would suffice to take out one brick and to replace it, as it had been done for crucibles, by a water-brick, or by a brick by which the matter in its molten state would cool down. He believed, therefore, that this system might be applied to furnaces as high as those in the Middlesbrough district. The strength of this construction was especially due to the lessening in thickness of the masonry. It was the expansion which the heat gave to the bricks which led to the giving way of blast furnaces.

The President, in accordance with the desire expressed by Mr. Whitwell, would just mention shortly the general tenor of M. Buttgenbach's reply. He (M. B.) had shortly gone over his paper and repeated the advantages which he conceived were attendant upon his new form of blast furnace. He mentioned particularly that, the top of the furnace being kept cool by the thinness of the walls, its action was not liable to become impeded by the formation of scaffoldings, which he imagined happened more or less in furnaces having walls of a thicker description. Now, no doubt when they blew out their furnaces—as was well known—the whole fabric of the furnace appeared to have been subjected to a very high temperature; but they must not allow themselves to be misled by those appearances, because there was little doubt that all the indications of high temperature of the interior of the furnace took place, not during the time of the working of the furnace, but were

occasioned by the intense heat prevailing in blowing the furnace down. Of that there could be little doubt, because such of them as had had an opportunity of looking into a furnace while it was at work must have observed that when at work the higher portion was comparatively cool. The last one constructed at the Clarence Works had a series of openings pierced in the sides from the top of the boshes to the charging plates. He (the President) had repeatedly examined the furnace in question, and he did not hesitate to say—at least so far as the first 30 feet of the furnace was concerned—there need be no fear of scaffolding taking place from the high temperature in that portion of the building. Then M. Buttgenbach also attached some importance to the introducing of the blast at different levels after the furnace had stood for some time. Well, that was an abnormal state of affairs, and when unfortunately this difficulty had to be met it was perhaps easier to pierce the sides of a furnace in order to get the blast introduced than to have recourse to all those tuyeres which were constantly there, and had to be kept cool by means of water, because this meant a certain amount of heat absorption; therefore, unless it were absolutely necessary to cool a furnace by the application of water, he (the President) thought that the less of that they dealt with in the structure the better. Of course, if he (the President) was correct in supposing that the contents at the top of the furnace were comparatively cool, as he had just stated, and not in a state of semi-fusion, as M. Buttgenbach assumed, then, of course, the idea of thin walls of a furnace of great altitude offered no advantage of importance. M. Buttgenbach imagined that, the materials being all in a state of semi-fusion, there was but little lateral pressure, and no doubt that would be the case if the materials were fused, but inasmuch as 30 or forty feet in their furnace—he was speaking of furnaces 80 feet in height, to which the observations of previous speakers had been directed—were not in a state of fusion, then they did require a considerable amount of strength in the walls of the furnace itself. After all, the great question was one which had been very incidentally touched upon, viz.: What were the merits of the furnace, judged of by its performance? It was quite easy to devise innumerable forms of blast furnaces, but then the question was, how much better was a new furnace than an old one? With regard to the

work performed by the blast furnace, they had to deal with the economy of fuel. That was the only question of any importance that presented itself to their eyes, and he (the President) had not learned that the furnace devised by M. Buttgenbach possessed any great advantages over the furnaces of their own country. M. Buttgenbach seemed to attach great importance also to the facility of repairs, and no doubt—with a wall 18 inches thick—in the event of any part giving way, they could easily get at and repair it; but their experience, he thought, was this, that furnaces were driven almost as long as it was possible to drive them economically, this being determined by the state of the lower part, viz., the crucible. He (the President) had never heard in Cleveland of a furnace being blown out because the cone had got into a state of decay; it was always the lower part that got out of order and required repairing. M. Buttgenbach spoke of a furnace in blast for 8 years; his (the President's) friend, Mr. Thomas Whitwell, who had addressed them, had furnaces which had been blowing 11 years—he thought he was correct in making that statement. (Mr. Whitwell: Yes, quite right.) His friend, Mr. Neilson, said he had furnaces that had been 13 years in blast. He (the President) quite agreed with what Mr. Williams said as to the arches; their pillars he believed were infinitely better. That was no part of the system itself, because Professor Jordan had told them that in the South of France they had constructed furnaces not with arches but with pillars. The pillars enabled them to get the hot blast stoves very much nearer than when masonry was employed, and so avoid loss of heat in the conveyance of the blast to the furnace, and he (the President) imagined that anything saved in the thickness of the walls was more than met—so far as experience was concerned—by that complicated system of pillars used for supporting the platform on the outside. With what Mr. Thomas Whitwell said, regarding the inconvenience of the gas passing over water, he entirely agreed. He had no doubt they would find the heating power of the gas would be very much lessened by introducing the vapour of water. At the same time they were very much obliged to M. Buttgenbach for having brought before them his novel furnace, and he (the President) had no doubt he would excuse them if they did not look upon the offspring of his mind with the same favour as he himself did.

The following paper was then read :—

ON THE ECONOMICAL PREPARATION OF IRON FOR THE DANKS PUDDLING FURNACE.

BY MR. CHARLES WOOD, ENGINEER, TEES IRON WORKS, MIDDLESBROUGH.

IT will be fresh in the minds of the members of this Institute that at the meeting at Dudley, in August, 1871, in the session of our worthy ex-president, that Mr. Danks brought before your notice his revolving puddling furnace. The very satisfactory statements made by Mr. Danks on that occasion resulted in a commission being sent out by this Institute to America, to examine into the whole question, and the very able report of the scientific investigation of those gentlemen is well known and appreciated by all those who are in any way connected with the iron trade. Some of the few defects pointed out by these gentlemen are the very large quantity of coal consumed per ton of puddled bar produced, and the destruction to the lining of the furnace when charging with pig iron. This destruction arises from two causes. Firstly, the pigs are generally broken in halves, and are put into the rotary furnace in charges of about half a ton each. The melting of this pig iron is the most serious item to contend against; the pigs lie in the bottom of the furnace impenetrable to the heat; the rotatory furnace cannot be set in motion except with the greatest caution, for fear of the pigs rolling over and knocking the lining to pieces; even with the greatest care half an hour is often spent in preparing the lining for the next charge. Secondly, there is also considerable damage done to the lining of the furnace and the iron produced by the presence of a large quantity of silica, which is introduced with the pig iron in the shape of sand. To meet these difficulties, the American Commissioners proposed to reduce the iron to a molten state before introducing it into the furnace, and no doubt at first sight this appears to be the right thing, but somehow or other, from causes I am unable to explain—not having had sufficient practical experience—the yield of the iron and the quality is not so good as when the cold iron is charged; perhaps it may in some way be accounted for by the fact that the molten iron does not

take up so much from the fettling, and again, the molten iron not being so long in contact with the fettling, may not part with so much of its impurities. Then again, there is the serious cost of melting by the cupola, which cannot be done much under the following sums:—

	s.	d.
Waste of iron in melting 4 per cent.	4	0
Carrying metal		6
Wear and tear of cupola and tools		3
Coals and engine power	1	7
Charging and working cupola	1	5
Coke for melting, including charging 3½ cwt. at 38s.	6	7
Limestone		1
	14	5

Making 14s. 5d. per ton before it goes into the rotatory furnace. These figures are obtained from a cupola running 40 tons per day, and are a fair average cost. It will, therefore, be seen that although the cupola process is undoubtedly a saving over the system of melting the pigs in the rotatory furnace, yet that it is an imperfect and very costly process, and it is with an idea that I have succeeded in overcoming all these difficulties that I have the pleasure of reading this short paper before you. I had the honour at the last meeting of reading before you a paper on the utilization of blast furnace slag, and I then showed my models and system of granulating the slag as it flowed from the furnace, as well as samples showing the perfect manner in which the granulating and cooling is effected. These samples, for the information of the gentlemen here present, I have pleasure in showing again on a small scale. The perfect granulating action of the machine induced me to try its effect upon iron, and I ran the iron straight out of the furnace into the machine, and produced the sample of iron on the table before you; the application of this to the Danks's furnace at once suggested itself, and at Mr. Danks's request I tried a larger quantity; this has been since used in one of the rotatory furnaces at work at the Tees Side Iron Works, Middlesbrough, with the greatest success; the charges are brought out in about 35 minutes, the quality of the iron is very superior, and the yield quite as good as if pigs had been put in, whilst the lining of the furnace is little the worse. It will be seen that by charging the furnace with the granulated iron, the

machine can be set revolving at once, thus exposing the whole surface of the iron to the heat which is speedily taken up, and the iron is melted in an incredibly short time. The iron runs from the furnace into a big ladle or dam whence it is tapped out—in the same way as from a cupola—in a small stream into the machine, so as to keep it under control and avoid all possibility of explosion. A sample is taken from each tapping to show the quality of the iron in its granulated state, the iron is delivered by the same machine at one operation into iron trucks, whence it can be delivered direct to the puddling furnace. The action of the machine will be better understood by consulting the drawing. You will observe that it is made in a shape not unlike a rotatory puddler, only much larger, being from 12 to 14 feet in diameter, and having sides, so as to enable it to contain between 3 and 4 feet of water. This cylinder is kept in motion by a small steam engine, and will make from five to six revolutions per minute, according to the size the iron is required to be granulated. You will notice that there are a series of buckets or agitators, which, being fixed to the cylinder rotate with it. These buckets or agitators passing through the water, keep it in a violent state of motion—the water having a tendency always to rush to the bottom—but meeting with the buckets, it rolls over in a violent manner. Into this water, the small stream of molten iron is run, and is scattered as it were in the body of the water, where it is held in suspense sufficiently long to prevent its touching the plates at the bottom whilst in a liquid state, and thus all possibility of explosion is avoided. On this point alone rests the failure of all former attempts to granulate iron in water.

The buckets or agitators also elevate the granulated iron to the top of the machine, where it drops into a spout, and thence into railway trucks or wagons holding about a charge for the puddling furnace. In conclusion, I would wish it to be understood that I do not claim the invention of granulating iron as new, as, to my own knowledge, it has been more or less tried during the past twenty years; but what I do claim is the very simple and inexpensive mode of producing granulated iron, and one which will at once offer itself as a practical solution of the difficulties before named, and which is calculated will effect a saving of at least ten shillings per ton on the finished iron.

Mr. Danks said the paper they had heard read by Mr. Wood brought to their notice a very important thing connected with the puddling of iron; as Mr. Wood said, it was a subject that had occupied the minds of practical men for a long time. He (Mr. Danks) had had more or less to do with granulated iron for the last 20 years ; not granulated exactly in the way Mr. Wood accomplished it, he had generally had ways of his own—not always successful ones,—but there were some advantages claimed for Mr. Wood's system of granulating iron which he (Mr. Danks) thought it would be wrong in him to let pass without some notice—one was the cost of melting pig iron in the Danks furnace. With regard to the claim that it cost 14s. per ton to melt iron in a cupola, he certainly did not know what it would cost in England or in Belgium ; he was very credibly informed, however, that it cost 8 (eight) francs a ton in Belgium, and in France also, to melt iron in a cupola. He had been informed that it cost from 5s. to 6s. per ton in England. Now, what that machine saved in puddling would be simply what it saved in the melting. Then the question arose, what did it cost to melt iron in the Danks furnace ? If it cost less money to melt iron in a Danks furnace than in a cupola, it was very clear that the cupola produced a loss, and ought not to be used unless they had other advantages from it to cover up that loss. Now, there were advantages in that granulated iron that all of them would see at once—they got a clean iron, free from sand. It was not only put in a form or size to melt easily, and with waste of comparatively little fettling, but they got it clean and free from sand ; and he did not hesitate to say that the sand which stuck on the outside of pig iron was a more serious evil in puddling than a great many of them were aware of. He had had his attention called to that for a great many years. They knew that sand did combine with the oxide lining of the furnace, and reduced the oxide of iron into a silicate, in which condition it was of no further value for the lining of a puddling furnace, because it melted at too low a temperature. Now, if they got a clean iron absolutely free from sand, they saved all that waste of lining. If there was no sand there, or other impurity, to combine with the oxide of iron, of course the oxide of iron would not melt to waste. But what would it cost to melt pig iron in the Danks furnace ? If Mr. Wood could save 10s. per ton in the working of the Danks furnace, it could not be saved in the melting, because

it did not cost that sum to melt in the Danks furnace. It took about one-third of the time to melt that was required for the puddling of a charge. Of course, no fixed time could be set for the melting of the iron; iron with a large percentage of carbon melted much sooner, and at a lower temperature, than iron with only a small amount of carbon. Some charges of iron required 35 to 40 minutes to melt—there were other irons that melted very readily in 20 minutes; so that he thought they might fairly assume that the average time of melting was half-an-hour. He thought that was rather beyond than inside the time required for melting in a Danks furnace. Now, he thought, it would be very difficult to burn over three tons of fuel per day in a Danks furnace, let them try their best. He would assume that the furnace would burn three tons of coal per shift, and make 6 heats per day, charging cold pig metal, although it would frequently make eight heats per day even when charged with cold pig metal; but he would assume for the purpose of his argument that he could make six heats a day, charging cold pig metal, with half-a-ton to each charge, which would give them a yield of three tons per day. He took it that was much below what the furnace was capable of producing for the purpose of showing what it actually cost to melt. Now, if it took three tons of coals per day, and he understood the cost of coal in Middlesbrough at that time was 15s. a ton, it would then cost 45s. per day for fuel for melting and puddling three tons of iron in a Danks furnace each shift. They might add to that the cost of labour, and he thought if they put the labour at, say 8s. a ton, that would allow each furnace 24s. a day for labour for working it. He thought if they put it at 8s. a ton they would put it at rather a high figure, in fact, at a very high figure. Now, if they expended one-third the fuel used in puddling for the melting, and used up one-third of the labour also, they had an expenditure there of 7s. 6d. per ton. Then the question arose, was it fair to charge the melting with the labour? He simply named that for the purpose of taking all the charges that were possible. Was it fair to charge the melting of the iron with the labour, because it must be borne in mind that while the melting was going on the labour was at rest, but he would assume that the labour properly belonged to it. Then there was an expense of 7s. 6d. per ton for melting. Now, they could melt, as he had already observed, six heats a day from cold pig; if

they could make one heat per day more with granulated iron than with pig iron, of course the granulated iron should be credited with that saving, because they then saved one-seventh, or 7s. 6d. per ton. That would represent the saving. If they could make two heats a day more than with cold charges of pigs, it would be just double that; but the saving in that granulated iron, taken purely on the cost and labour question, would not effect a saving exceeding 2s. per ton, but as he had already observed, there were other savings. There was the saving of the lining, and he (Mr. Danks) himself thought they might save in improved quality of product also with some kinds of iron, but that would not apply to all kinds of iron. The saving by granulation was not as great with all kinds of iron as by some kinds, but they would get a greater yield with clear granulated iron, and the lining would not be wasted by the sand and converted into a silicate. They might very reasonably conclude that the carbon in the pig iron would take up a considerable portion of oxygen of the lining, and the iron be improved in quality. Any process of granulating iron would not apply to all kinds or grades of iron. Take, for example, cast iron borings. Very fine borings did not melt in the puddling furnace, and good quality is impossible where the charges do not melt well. They had made as high as fifteen heats a day in America from fine borings, and the iron squeezed well, and rolled well, and the bars were just as sound apparently—and as smooth—as any bars they ever saw; in fact they were more like re-heated bars in appearance than ordinary puddled bars, but the bars they found were exceedingly weak, and unless they brought the charge to a liquid state in the furnace—not merely heated it, but brought it to a liquid state, they never did produce such good results as when it was brought into that state. The bringing of it into a liquid state he regarded as a very important point, and some iron would not melt in the puddling furnace if reduced to a very fine or small condition. Now, they used what they called stove castings. In America they used them in all their buildings, and thousands of tons were used up every year. In their works they used as much as 2,500 tons in a year, all puddled in the Danks' puddling furnace. Now, those plates varied from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch in thickness; of course they melted very well, and the yield from such plates was simply enormous. The iron in these plates was rich in carbon, and any

iron that can be made fluid in the puddling furnace at an ordinary temperature being reduced finely should be so reduced, but some grades of iron would not melt if reduced fine, and should be made into larger pieces. Ordinarily they puddled 8 (eight) heats per shift of cold pig iron, and when they changed on to those old stove plates the uniform product was 10 heats per day. That was just as regular a practice as anything could be—10 heats per day—and the increased yield over pig iron was generally from 5 to 6 per cent., and sometimes the gain had been as high as 21 per cent. over the charge put into the furnace. That was by no means regular, but he thought he was quite safe in saying that the average gain in puddling with those plates was 15 per cent. Now, in making experiments with granulated iron, made from iron very rich in carbon, and which would melt easily and become liquid in the puddling furnace at a low heat, they produced very good results; as good indeed as any that could be produced from best pigs. He had made some figures, based on former experience, to show what he thought would be the saving from iron properly granulated. He did not wish to be understood as casting any reflection upon Mr. Wood's machine at all, but there was a certain amount of irregularity in the size of the iron so granulated, still it was a great improvement over pig iron. He (Mr. Danks) regarded the making of pigs for puddling in the revolving furnace as being simply barbarous, and thought it ought to be abolished. That granulation was a great improvement upon it. He took this ground, that where the metal could be taken direct from the blast furnace in a molten state, that was the best possible way of puddling that iron. That we should set down as No. 1. But that could not always be done, but where it could be done it ought always to be taken advantage of, and never be allowed to be put in the shape of pig; but where that could not be done, he should strongly advise anyone to granulate the iron as the next best thing, but iron that melted at a very high temperature should not be run into water; the gain would not be so great nor the quality as good as if it were put into those stove plates, or through rolls $\frac{1}{8}$ of an inch thick; they gained two heats per shift with thin plates, and that was in the early stages of the rotary puddling furnace, and at a time when he was dividing the charge into three or four balls. Now, he maintained that the iron should be so divided or

granulated as to be of uniform thickness for the same grade of iron, and enable it to melt altogether in the furnace; if they had large and small pieces in the same charge, the small pieces would melt before the large pieces and results would not be as good. He (Mr. Danks) had heard of a machine for granulating, that did reduce the molten iron into thin plates. He had no interest in either machines, but believed that the roll machine would be preferable in some grades of metal than the water granulator. He had seen some samples from it, and they were reduced to sizes favourable for melting uniformly in the puddling furnace, either of those machines would granulate iron very well, and it would be an improvement with any kind of metal over the running of it into sand moulds to make pigs of, and he did insist upon it that there would be certain grades of pig metal which the water granulator would not be suitable for. The running of it into water would make it exceedingly difficult to melt. Some people thought that cast-iron oxidised very rapidly when it cooled after being wet. He did not share that opinion, nor when a small quantity of oxide formed on the outside of granulated iron. It would simply take up a little less of the oxide in the furnace. If reduced to a thin plate, he cared not whether it was run out on a clean plate floor, or passed through the rolls, if they got a uniform thickness of iron and then freedom from sand, in his opinion, that was as good a way as granulating; he cared not whether it was in broad plates or in small pieces, but if they got it too fine, like fine roll turnings, with some grades of iron the quality would be injured instead of improved. That was what he wished to insist upon. It should be so granulated in size as for every portion to be brought into a liquid state in the puddling furnace. Iron containing large quantities of silicon or carbon would admit of being reduced to smaller pieces than iron deficient in them, and he thought the very best that could be done in point of saving would only be just what was saved by the melting and saving of lining in the Danks furnace. If the Danks furnace was capable of puddling six or seven heats per day without granulation, whatever number of heats it could make in addition to those, the granulating process would be entitled to credit for, and for nothing beyond that; but he did say this, that if iron cost 14s. per ton, or 10s. per ton in the cupola, then he should recommend people to keep their money in their pockets and not melt in a cupola. That

was his view of the matter, if, as he was told by a gentleman there, it cost him 8 francs per ton in France to melt iron in a cupola. That was justifiable. That was the amount of saving in the puddling furnace, but if it cost in England over 6s. per ton, or 6s. 6d. at the most, there would be no saving in changing molten metal melted in the cupola, but there would be a decided saving in using granulated iron, and taking granulated iron as a rule, he believed that some iron would be very much improved in passing through that machine; but that was mere speculation, and as he understood that Institution was for the purpose of getting reliable information, it was hardly worth while spending time in speculations; he would, therefore, simply say that so far as that machine was concerned, he believed it would be a very good machine indeed for Cleveland iron, but he still believed there were other means of granulating iron that would make it much more uniform in size than that machine.

The President thought Captain Bodmer had done something about separating iron, and called upon him to give them the result of his experience.

Mr. Bodmer said that his mode of subdividing iron consisted in passing the same, in its molten condition, direct from the blast furnace, through a pair of plain rolls. When the rolls rotate at equal surface speed, the iron issues from them in the shape of sheets, peeling off in pieces of varying sizes. The size of such sheets or pieces is, however, easily regulated when the rolls are made to rotate with differential surface speeds, and by this means the subdivided iron can be produced at will, from a considerable size, and say $\frac{3}{32}$ of an inch in thickness, down to the minutest scale. Water is passed through the rolls, to keep them sufficiently cool, and the iron drops on a shaker underneath, from which it falls into a truck, or other receiver. Rolls of 24 in. diameter, and 20 in. working length, $\frac{1}{16}$ in. apart, taking through about 96 cubic inches, or 24 lbs. of iron per revolution, will produce a ton of subdivided iron (the rolls making about 94 revolutions) per minute. Whilst granulation in water may, under circumstances, give rise to explosions, no danger is to be apprehended in the rolling process, and the rolled iron has the advantage of offering the largest possible surface to the flame in the puddling furnace. Experiments were made for the purpose of ascertaining the effect of mixed charges. That is to

say, the subdivided iron was mixed with the quantity of oxides required in the puddling process. Charges of 4¼ cwts. were spread in layers of equal thickness over the whole of the furnace bottom, and in four or five minutes after closing the furnace door rabbling had to be commenced. About a dozen charges were made, in from twenty-three to twenty-five minutes time, charge for charge, with perfect regularity. The statement which Mr. Danks made, relating to his experience in puddling iron, charged in the shape of stove-plates, would apply in every respect to iron subdivided by rolls, and charged in the usual way.

Mr. Wood said Mr. Danks had made some remarks upon the figures he produced for melting iron. He (Mr. Wood) was aware that there was a very great discrepancy between his figures and those produced by other people; but it was very difficult to arrive at the actual cost of melting without examining the whole cost from beginning to end. It was not a simple matter of coke—there were other questions attached to it, such as carriage of metal, blast, lime, tools, wear and tear of cupola, &c. Mr. Thomas's cupola worked with the least trouble and expense; his was the best cupola and would melt iron at the cheapest rate; at the same time, he did not believe Mr. Thomas could melt iron in the cupola, and carry it to a Danks furnace, under 10s. a ton. He said that very cautiously, because he knew very well what costs were. In making his (Mr. Wood's) comparisons about the introduction of granulated iron into the Danks furnace, they must please understand that he made those remarks with the intention of drawing a comparison between the melting of the iron in the Danks furnace and in a cupola. He simply took the actual facts arrived at by the Commission sent out to America as the basis of his conclusions. With these facts only he dealt—that was, with reference to melting the iron in the cupola and introducing the melted metal into the Danks furnace. His paper referred only to that. He said nothing about melting the iron in the Danks furnace—the American Commission went fully into that. As far as granulating regularly was concerned, that simply depended upon the velocity at which the machine was driven and the depth of water. It was merely a question of driving the machine regularly, and regulating the flow of water into the machine. So far as running cast iron plates in the way Mr. Danks mentioned, he thought that most of them

would be acquainted with the cost occasioned by the wear, tear, and cost of chills. Then, again, there was the enormous surface of flowing required for making plates three-eighths thick by this plan, and the cost of breaking up and loading into trucks—this could not be done under 1s. 6d. per ton. If Mr. Danks were to chill his iron in the manner proposed, he could not possibly break it up so small as the granulated iron, consequently it must take longer to melt and work chills; and iron could not be chilled in any way without considerable wear and tear. They knew that from their experience of the cost of renewing chills in the ordinary refinery furnace and the chills used on the pig beds; but, in his machine, the molten iron never came in contact with the metal plate. The heat was taken up by the water, and, as soon as it got to a boiling heat, it was thrown off again in the shape of steam, so that there was comparatively no wear and tear. To a certain extent, those remarks also applied to any mechanical apparatus where molten iron came in contact with cold iron. If they brought molten metal into contact with cast iron continuously, there was always a certain amount of contraction going on, and it must end in considerable wear and tear.

Mr. Danks said that in the remarks he made he did not intend to cast the slightest reflection on Mr. Wood's machine. He thought it was a very valuable machine, and all he had wished and attempted to do, was to draw a comparison.

The President: Mr. Wood has explained that you are merely drawing a comparison between this and the cost of melting in your furnace.

Mr. Danks: My position is that if it costs what Mr. Wood's figures show, the cupola ought not to be used.

Mr. Edward Williams thought the figures given by Mr. Danks and those by Mr. Wood could be reconciled, by bringing down to the level of ordinary prices the estimates Mr. Wood had made. He (Mr. Williams) imagined that forge iron would not stand for ever at 100s. a ton, as Mr. Wood had assumed it would. Taking 62s. 6d. as an average price for the future, the item which Mr. Wood estimated at 4s. per ton would come to half-a-crown. Coke was put by Mr. Wood at 38s. a ton, and it was not unreasonable to expect that over an average of years it would be probably about 20s. per ton. Taking 2 cwts. to the ton of iron to be used in the cupola,

instead of 3½ cwts., Mr. Wood's estimate of 7s. would be brought down to about 3s. Mr. Williams thought that labour was put in higher than it need be; but merely correcting the prices of coal, coke, and pig, to what they probably would average over a term of years, that which by Mr. Wood was estimated to cost 14s. 6d. per ton, would, in Mr. Williams' opinion, be no more than 8s. 2d., or very nearly Mr. Danks's estimate. As regarded casting pig iron in chills, he would only say that it was being done very extensively at works under his management, and the cost of the chills was less than that of sand in ordinary pig beds.

Mr. Crowe handed to the President some specimens of iron granulated by pouring it into the river Tees, the metal in falling through a column of water formed into granules of a hollow globular form of the size of an ordinary pea. Granulated iron in this form took 40 minutes to puddle in the Danks furnace. Molten iron from the cupola took 50 minutes to puddle in the same furnace.

The President: Effecting 10 minutes saving.

Mr. Crowe: Yes.

Mr. Crowe: Here is some of the iron (handing some to the President) which was puddled in 40 minutes, rolled into angle iron 70 feet long, and of excellent quality.

The President: Mr. Crowe, did you find any effect on the lining of the furnace.

Mr. Crowe: When the iron was thrown into the furnace, and the furnace was put into motion, the granulated iron adhered to the fettling, which must have had the effect of chilling the fettling to a certain extent.

Mr. Whitwell said it would be very interesting if Mr. Crowe would tell them something about the yield and quality of the molten iron.

Mr. Crowe thought that as regards the difference of yield and quality between disintegrated and molten iron puddled in the Danks furnace, hardly sufficient experience had as yet been obtained to speak with any degree of certainty in that respect.

The following paper was then read :—

NOTES ON THE BELGIAN COKE MANUFACTURE.

By M. AUG. GILLON, Professor at the School of Mines, Liége.

THE carbonization of coal in large mounds, in the way practised in Wales and in Staffordshire at the present time, has the advantage of not requiring the erection of expensive structures, and calls for nothing but a slight preparation of the surface. It has, however, the disadvantage of necessitating the use of bituminous coal, a great portion of which has to be in lumps. The coke obtained is wanting in uniformity of quality and density, and the yield is comparatively small. Coal, which in well-constructed ovens produces from 75 to 80 per cent. of coke, will, by this primitive process, yield but from 60 to 65 per cent. These figures show that the manufacture of coke in mounds is only justifiable where building material is high-priced, and coal very cheap. As the price of coal rises, so does the necessity for abandoning the whole system, and for adopting the method of carbonizing in special ovens increase. This is only attracting attention in England at the present time, whereas Belgium has long since passed through the period of transformation. In 1852, the extraction of bituminous coal necessary for the manufacture of coke by the means then employed became insufficient in the Charleroi district, and the price increased to such a figure as to threaten serious injury to the iron trade. It was, therefore, found necessary to economise fuel and to find out means for manufacturing coke out of semi-bituminous coal, which circumstances were the means of bringing numerous varieties of ovens under the notice of the industrial community. Very shortly after the same question affected the district of Liége, and during the visits which the members of the Institute are about to make in this locality, they will have opportunities of seeing many different forms of coke ovens all in full operation, and each of which solves some peculiar problem for which it was specially devised. These problems are such as have a bearing on the nature of the raw material, on the yield, on the quality of the products, on the expenses of labour, and on the first cost. We will now enter into an examination of the different forms of coke ovens.

It has always been easy to make good metallurgical coke from bituminous coal, but when the production of this coal became insufficient, it was found indispensable to allow the introduction of inferior coal. This object was attained by a gradual reduction of the width of the ovens, and by calcining the coal in narrow compartments greatly heated externally by the flames of the adjoining ones. Semi-bituminous coal suddenly heated by these flames agglutinates and makes a good coke.

In view of obtaining a larger yield, the coal has been carbonized in close vessels, that is, without the admission of air into the interior of the ovens. In this case the gases distilled from the coal circulate in flues which surround the retort, and are thoroughly burnt within them by means of a well-regulated introduction of heated air. The heat developed by the combustion of these waste gases effects a most economical carbonization of coal. The rapidity with which the ovens have been charged, discharged, and the coke extinguished, has also had a favourable influence on the yield.

Uniformity in the coke depends on the dimensions of the oven, and in an arrangement of the flues through which the flames circulate. A certain influence is also attributed to the use of double doors. The solidity of the coke depends principally on the previous crushing of the coal, and on the height of the charge in the narrow oven. The purity is assured by means of a careful washing out of all extraneous matter from the coal.

Economy in labour has been attained by the substitution of hoppers and tubs or trolleys for feeding the oven, instead of the old plan of throwing the coal through the door by means of shovels. Another form of economy consists in the employment of a steam ram for discharging the coke in lieu of hand labour and a hook. The extinguishing is done by means of a hose and nozzle instead of the primitive bucket. With the same object in view, all our most recently constructed coke ovens have been erected on three different levels, the first, or highest, being employed for the circulation of the charging trolleys, the second for discharging the produce of the ovens, and the third is level with the railway, the coke being sent away on it in regular railway trucks direct on to the main line. The level for discharging is immediately above the top of the railway cars to be loaded. The superficial area which is occupied by a number of these furnaces may, in certain cases, become a

question of great importance, and in such instances the vertical ovens present very palpable advantages over the horizontal.

It is impossible in this paper to give the history of every kind of coke oven in existence, so that we shall limit ourselves now to a description of those which the excursionists will meet with in the neighbourhood of Liége. We cannot, however, proceed without calling your attention to several interesting kinds employed in the districts of Charleroi and of Mons, which owe their origin to some of our most distinguished engineers, such as MM. Eugene Smits, Martial Fromont, Letoret, and Gendebien.

The old forms of ovens, with solid walls, which are known as bakers' ovens, and which are discharged by means of a rabble, many of which are still to be seen in England, have long since disappeared in Belgium, where they have been replaced by ovens having flues, and being emptied by steam power. The best way of indicating the value of this transformation will be to exhibit at one view the cost of producing coke by the two systems, as was done at some works:—

COST OF THE PRODUCTION OF 1 TON OF COKE IN OLD OVEN.

	FR.	C.
1,538 kilos. of coal at 10 fr. 78 c. per 1,000 kilos.... ...	16	58
Labour	1	00
Repairs, Carriage, &c.	0	75
Total cost of 1,000 kilos. of coke	18	33

COST OF PRODUCING 1 TON OF COKE IN SMET OVEN.

	FR.	C.
1,330 kilos. of coal at 10 fr. 78 c. per 1,000 kilos.... ...	14	37
Labour	0	66
Repairs, Carriage, &c.	0	85
Total cost of 1,000 kilos. of coke	15	88

Showing a difference in favour of the Smet oven of 2·45 fr. per ton.

The Smet system, of which we have just spoken, is in existence in this locality at Ougrée, at Seraing, and at Grivegnee. It is an oven with two doors, and a mechanical ram, which, by-the-bye, is universally used in Belgium. The dimensions of this Smet oven

are:—Length, 7 metres; width, 0·65 metres; height, 1·60 metres; charge, from 40 to 45 hectolitres; and the time required in making the coke varies from 24 to 36 hours. The coke is introduced through hoppers. The flame from a working oven penetrates into openings at the basis of the arch, and follows two horizontal flues, then it circulates under the sole, and from thence reaches the chimney. When semi-bituminous coal is used, the flames are employed to heat the sole of the adjoining oven rather than the sole of the one in which they were produced.

Modifications have been introduced in the disposition of the flues, so as to avoid the destruction of the brickwork, and also to facilitate the cleaning out of the passages. The blast furnaces of Ougrée are working ovens modified in this way by M. Chevaux. M. Gilbert, in order to obtain the same results, has replaced the horizontal flues by vertical chimneys in several different works in the province of Hainaut.

The Smet oven, after being very successful both in this country and also in others, seems in course of being superseded by other systems, and more especially by the Dulait ovens, by the Coppée ovens, and by the Appolt ovens, all of which we shall describe.

In a group of ovens on the Dulait system, the ovens are placed in pairs—one oven heating the adjoining one. This division in couples exists also in the Coppée system. It allows of the extinction at will of any portion of a group of ovens, while the remainder are kept in full operation. The flames descend directly below the sole, where they are divided into four currents which flow in between the partition walls, and after traversing every flue they reach the chimney. Their length is 7 metres; width, 0·75 metres generally, but is variable according to the quality of the coal; the height to the base of the arch is 1·15 metres; the height of the arch 0·10 metres; and the incline of the sole towards the discharging level is 0·02 m. per metre. In order to avoid waste of heat as well as the action of the winds and of the penetration of air, these ovens are furnished with double doors, the interior doors being of cast iron, the outside doors level with the face of the structure, at a distance of 0·30 m. from the preceding ones. The outer doors are of sheet iron, of a thickness of 0·005 metres. The disposition of these doors reduces the space really occupied by the coal in the furnace to a length of 6 metres. Carbonization in a close vessel is

one of the principles on which the Dulait system is based, in consequence of which, all the doors are carefully closed all round with clay. The hoppers for charging the ovens are also closed both at the top and bottom, the lower part being shut in by a cast iron slab cemented with clay on the brickwork, and the upper portion has a cover, the edges of which rest in a channel filled with powdered coal.

The carbonization in a close vessel gives a maximum yield. But if air is excluded from the oven and does not consume a portion of the coal during combustion, we, however, must be able to obtain the heat necessary for the coking operation. M. Dulait following out the idea already put forward in England by Mr. Cox, has attained the desired result by burning the gases in the circulating flues by means of the introduction into these flues of numerous jets of heated air. In order to provide for this, one of the walls of the flues through which the gases pass is built of two rows of hollow bricks, superposed. These bricks have a section of 0·10 metres by 0·12 metres. They are pierced by a longitudinal hole 0·05 metres in diameter, in such a manner that, by their juxtaposition, they form two superimposed channels as long as the whole flue. The lower channel is open at the front of the oven and closed at the other extremity, where it rises in order to communicate with the upper parallel channel. This is pierced by holes 0·008 metres in diameter, placed at a distance of 1 decimetre from each other, and opening into the flue in which the combustible gases are circulating. By this arrangement the external air taken in by the draught penetrates into the lower channel, where it gets heated, and, reaching the upper passage, is projected across the stream divided into innumerable streamlets, which increase the surface of contact, thus effecting perfect combustion of the gases, and producing the highest possible degree of temperature, so that the gases are in this way fully utilized. As a result, if the coal is of the right quality, the combustible gases are produced in sufficient quantity to admit of the complete distillation of the coal, and the heating of the whole of the apparatus in a regular and permanent manner.

This system does away with the necessity for providing openings for draught, or reduces it to a theoretical absence of draught, limited only by the care with which the clay has been applied to the doors.

The Dulait system has been very much discussed and criticized. Many unfavourable opinions have been expressed in regard to it. Some persons claim for it a marked superiority over all others, while other parties, although recognising the ingenious disposition of the parts, do not think it can be employed in the case of bituminous coal. Some again, after practical experience, remain undecided as to its value when the first cost is taken into consideration.

At the John Cockerill Works, at Seraing, these ovens have been discarded, the engineers in that locality believing that the bituminous coal of that region produces a denser and harder coke in the ordinary ovens, which are put up at only half the expense. At the establishments of the Société de Witry, at Ougrée, one group of Dulait and another of Smet ovens have been built side by side for the purpose of comparing their working. The dimensions of the Dulait ovens are:—Length, 7 metres, 6 of which are occupied by the charge of coal; width, 0·74 metres. The charge is 2,200 kilos., and the operation lasts 24 hours, the yield being 78 per cent. The dimensions of the Smet ovens are:—Length, 7 metres, entirely occupied by coal; width, 0·68 metres. The charge is 2,000 kilos., and the operation lasts 24 hours, the yield being 77 per cent. The first-named furnace gives off much less smoke than the second, and although the Dulait apparatus costs considerably more to erect, and is less easy to manage than the other, the Société have decided, after examining the subject in all its bearings, to adopt it in their establishment.

The partizans of the Dulait system contend that their oven will give still better results than those furnished above, if managed with the necessary amount of care. They state that the coal used during the experiments made by the Société Cockerill, at Dolhain, at Bracquegnies, and at Seraing, can never produce less than 75 per cent. of large coke, whereas the Société testify that they have only obtained 71·34 per cent. Taking a theoretical standpoint, they affirm that ovens into which air cannot penetrate must produce more than the most carefully managed ovens into which a draught is admitted. At the works of Witry, at Ougrée, the Dulait ovens gave better results than those on the Smet principle, but the difference is very slight. M. Dulait does not doubt that he can effect a further saving of 3 or 4 units when greater experience has

been obtained in their management. It has been also stated that the Dulait ovens demand constant and careful attention, which the labourers cannot be brought to bestow upon them, and to this cause must be attributed the variations noticed in the results of the regular working of the ovens. According to M. Dulait, if this reason for non-success was admitted, we have here a negation to all industrial progress, and without leaving this region he quotes the results obtained at Dolhain and at Tilleur. The Société de Dolhain was in possession of a Smet oven, the average yield of which, during five consecutive months in 1860, was slightly lower than 71 per cent. The Société then erected 40 Dulait ovens, which, according to the report of the managing director, gave as an average for two months' working 79·17 per cent. of large coke of excellent quality, and 1·75 per cent. of small coke, or a total of 80·92 per cent. The Coal Company of Val Benoit and Grand Bac, after having made many trials with its own coal, gave the preference to the Dulait ovens, and built at Tilleur, in 1865, the first group of 30 ovens, the working of which gave such satisfaction that the firm were induced very soon afterwards to erect 30 more. Their average yield was 78 per cent. of very good coke, the charge of coal for 24 hours being from 2,300 to 2,400 kilos., according to quality of coal. Now, they work with a maximum charge of 3,600 kilos., which still allows of the withdrawal of the coke in one body. The period of carbonization lasts from 42 to 44 hours. Coke ovens on the Dulait system have been built for receiving a charge of 4,200 kilos., to be calcined in 48 hours. One of the objections to these ovens is the great expense incurred in their construction. We must admit that, with the actual prices of material and labour in this country, each Dulait oven with its mechanical ram, and designed to produce 2,400 kilos. of coke every 24 hours, will cost 2,700 francs; this without taking into account the cost of foundations or land. The engineers who prefer the Dulait system, believe that these ovens will last 10 years with but slight repairs, whereas the Smet apparatus needs every five years repairs, amounting to about half the first cost. If to this advantage of the Dulait oven we add the fact of its being a very hot oven, and working larger charges with a superior yield, this system will supersede the other, especially when semi-bituminous coal, or bituminous coal of inferior quality, has to be used.

M. Dulait has constructed in the different coal districts of Belgium no fewer than 1,100 of his ovens, and 700 in France, Prussia, and Austria.

The Coppée ovens are very highly thought of at the present time. Belgium possesses 524 of these in operation—several in the neighbourhood of Liége—and 192 others are being built. In Prussia, 1,305 are at work, and 138 are in course of erection. In France, 186 are in activity, and, in England, 30 are at work at the Coppée Coke Company's works, at Thorncliffe, and 30 more are being put up there.

An important and very complete notice of this system of ovens was recently published in the Transactions of the North of England Institute of Mining and Mechanical Engineers, March and April, 1873, written by Mr. Emerson Bainbridge, manager of the mines of the Duke of Norfolk.

As in the systems previously described, the Coppée ovens are placed together in groups of two and two. The flames from the two ovens of the same group pass through a series of openings made in the arch, and circulate through suitable channels around the oven, then passing beneath the sole of the adjacent oven, enter a common conduit, which first goes beneath the boilers and then leads to the chimney. The gases are burnt in the channels by numerous jets of warm air. Galleries under the brickwork are traversed by currents of cold air, which cool and preserve the construction. To diminish the loss of heat, the tops of the ovens are covered with a bed of clay about 18 in. thick, on which bricks are laid.

The ordinary dimensions of an oven are:—Length, 9 m.; width, 0·45 m.; height, 1·20 m., for a coking of 24 hours. For a coking of 48 hours the width is 0·60 m., and the height 1·70 m.

The ovens are quickly filled by three charging hoppers.

The characteristics of the Coppée furnaces are:—

1. A small width, and an arrangement of channels especially suited for poor coals.

2. A combustion of gas by a double admission of air, which entirely suppresses the smoke.

3. The combination of all the hot gases in a large conduit beneath the ovens, and their utilisation for heating boilers.

It is estimated that a furnace can heat a 3 or 4 horse boiler. This force is employed for breaking the coal, discharging the coke,

&c. A furnace gives 2 tons of coke per 24 hours. The duty is high, and the quality of coke produced extremely good. A furnace, including foundation, to a depth of 1·85 m. below the ground level, costs 2,500 francs. A group of 26 ovens, including breakers, discharging apparatus, wagons, distribution of water, boilers, &c., costs 106,000 francs.

It has been urged that the Coppée ovens are too light on account of the side walls, which are only 0·33 m. thick, including a space 0·09 m. for the passage of gas, but, from the experience obtained, we may safely assert that this criticism is entirely an unjust one.

Comparative experiments made in England with the elliptical beehive ovens and the Coppée furnaces give the following results, which we extract from the paper of Mr. Bainbridge:—

Summary showing Chief Points of Comparison between the Beehive and the Coppée Ovens.

	Common oven.	Coppée oven.
1.—First cost per 2 tons of coke per day	£119 7s.	... £100.
2.—Time Burning	48 to 120 hours	... 24 hours.
3.—Area occupied per ton of coke per day	1,218 sq. ft.	... 234 sq. ft.
4.—Per cent. of yield { Washed	45 ℔ cent.	... 59 ℔ cent.
Unwashed	54 ,,	... 68 ,,
5.—Area of outside cooling surface per 2 tons of coke per day...	1,002 sq. ft.	... 175 sq. ft.
6.—Time occupied in emptying and refilling ...	60 minutes	... 8 minutes.
7.—Units of heat in waste gases given off per oven per day	966,710	... 1,401,584.
8.—Labour charges (cost of coking) per ton... ...	1s. 3d.	... 11d.

The arrangements for charging and emptying show, also, a marked improvement in the yield, but M. Appolt, in placing the retorts vertically, and effecting the filling and emptying by gravity, appears to have made the greatest improvement possible in this detail. At Ougrée, and at Seraing, several groups of ovens are built on this system.

An Appolt group comprises 12, 18, or 24 retorts, ranged in two lines. Each retort is from 4 m. or 5 m. high. To facilitate the exit of the coke, the retorts are made to taper, so that at the top they measure 1·10 m. by 0·35 m., and at the bottom 1·25 m. by 0·45 m. The bottom of the retort is closed during the coking by a sliding door. The charge is made first with coke dust, with which a bed about 0·30 m. thick is formed. The charging wagon is then brought over the mouth of the retort and the load is emptied. The mouth is

closed with bricks and luted with clay, so that the charge is thus hermetically sealed.

By the heat applied at the sides the gases are distilled, and escape by small openings, 0·15 m. by 0·02 m. high, and placed 0·40 m. from the bottom. The gases are discharged into an annular space around the compartment, in which they are burnt, with air introduced through openings in the furnace. The heat developed by their combustion effects the carbonization of the coal. The products of combustion reach the chimney by means of twelve horizontal channels, fitted with valves, and arranged in such a manner as to distribute the heat equally over the whole group. To discharge the retorts, the door is opened, and the cake of coke falls into a wagon lined with fire-bricks. The coke is quenched by water.

The advantages which have been sought for in this construction are as follows :—

1. The calcination is effected in a close chamber solely by the combustion of gas disengaged from the coal, a condition favourable to a high yield.

2. The heating surface is very considerable, reaching 190 square metres for a charge of 1·5 tons. The comparatively small size of the retort secures a rapid and regular carbonization.

3. The flames from all the compartments, uniting in a common chamber, which surrounds them, insure a uniformity of temperature.

4. The vertical position of the compartments, besides the facility for rapid charging and emptying, gives more compactness to the coke, whilst the arrangement occupies less space.

The following are the inconveniences incident to the system :—

1. If the general arrangement does not allow of the coal being led direct out upon the loading platform, lifts must be provided to raise it.

2. Masses sometimes adhere to the sides of the retorts, which have to be broken by bars before the coke can fall.

3. The management of these ovens is not so simple as in some other systems, and when repairs are required for one compartment, the whole group has to be stopped.

At the works of Marihaye and Seraing, the compartments are 4·5 m. in height, of which from 3·20 to 3·40 are occupied by the charge ; the upper opening measures 1·12 m. by 0·29 m., and the lower one 1·25 m. by 0·43 m. This charge is composed, besides

115 kilos. of coke cinders thrown in first, of 1·2 ton of dry coal. The Marihaye coal, previously washed, is calcined in these ovens; 1 ton of gross coal gives ·890 ton of washed coal, ·095 ton of stones, and ·015 of dust. The time for coking is 24 or 26 hours. The percentage obtained is 78 per cent. with dry coal, and this rises up even to 80 per cent. The coke from these ovens is of a remarkable compactness and hardness, and is well suited for transport. Whilst ordinary coke weighs from 450 to 500 kilos. the cube metre, the coke at Seraing, made in the Appolt furnace, weighs 530 kilos. and sometimes 560 kilos. For a complete works, we can estimate the comparative cost of establishment per ton of coke, not washed, produced in 24 hours:—

System.	Francs.
Coppée	2,500
Smet	3,000
Appolt	5,000

On the other hand, the Coppée furnaces occupy double the area, and the Smet two-and-one-half times the area of the Appolt ovens, for an equal production.

The following paper was next submitted :—

STATISTICS OF THE MANUFACTURING AND COMMERCIAL MOVEMENT OF COKE IN BELGIUM.

By M. MAX. GOEBEL, Director of the Colliery of the Chartreuse, Liege.

The enquiry, established by the English Parliament, into the causes of the scarcity and high price of coal, has excited the greatest interest throughout the industrial world. Many members here present have taken a most prominent part in the enquiry. The link that now unites all industrial nations, had, before the results of the enquiry was published, impressed the minds of people on the Continent, and, particularly so, of those in Belgium, with the economical as well as social importance of the proceedings in England.

To render an industry prosperous, it is not only requisite to keep an attentive eye on the progress made in other countries, as regards machinery or new processes, but one must look into the causes which may decrease or increase the general production, as also into those which may open new markets or close others. In this point of view, I have undertaken to produce statistical tables, representing the commercial movement of coke in Belgium during the last three years. I do not think such tables have been published in Belgium.

PRODUCTION.

Belgium devotes, on the average, 14 to 16 per cent. of its coal production to the manufacturing of coke. This would give for the last year a consumption of two millions of tons of coal (Belgian ton = 1,000 kilogs.) Fifty-three firms are engaged in this important branch of Belgian industry—

	15	in the West of Mons	Basin.
	7	,, Centre	,,
	13	,, Charleroi	,,
	18	,, Liége	,,
Total...	53		

During the period of 1870 to 1873, two causes had a preponderating influence on the production of coke. The first was the war raging on our frontiers, thus closing partially the centre markets of France. The second cause was the great reaction, and the great stride of industry in general; particularly that of metallurgy, that followed after the war.

A remarkable fact, the war acted but slowly on the general production. The first six months of 1870 had been so favourable to industry, that there was compensation for the decrease in the productions, sustained on account of political events during the second half portion of the year. It was only in 1871, that the production decreased, and particularly so in Hainaut, and that on account of the great accumulation of stock and of the insufficient means of transport. After reaching, in 1870, 1,374,000 tons, the production in 1871 attains but 1,314,000 tons. In 1872, it comes up to 1,644,712 tons, and one foresees for 1873, the amount of 1,800,000 tons.

The following table gives the quantities produced by the different basins :—

Basins.	1870. Belgian Tons.	1871. Belgian Tons.	1872. Belgian Tons.	1873. Belgian Tons.
West of Mons...	248,697	224,581	322,642	341,300
Centre	261,262	267,626	304,631	305,480
Charleroi	390,877	412,229	474,484	541,166
Liége	473,703	430,479	542,955	650,150
	1,374,599	1,314,915	1,644,712	1,838,096

Adding to the above quantities produced, the quantities imported into Belgium, we shall have the quantities offered to industry in general.

IMPORTS.

The importation of coke into Belgium has, up to this year, been very small.

In 1871, the quantities	imported	were		3,000	Belgian Tons.
In 1870,	„	„	„	8,000	„
In 1872,	„	„	„	8,000	„

Since, it has been on the increase, and, looking to the quantities imported during the first five months of 1873, one can foresee for this year an importation of 38,000 tons of coke. France represents 3·8 per cent. of this amount. Then come England and Prussia, as the following table will show :—

IMPORTS.

	1870. Belgian Tons.	1871. Belgian Tons.	1872. Belgian Tons.	1873. Belgian Tons.
Prussia	4,414 ...	2 ...	360 ...	11,700
France	3,694 ...	3,189 ...	7,616 ...	14,580
England	— ...	2 ...	125 ...	12,372
Total ...	8,108	3,193	8,101	38,652

Let us now examine where these quantities of produced and imported coke are consumed, and to what degree in the different markets of Belgium and the neighbouring countries.

EXPORTATION.

The Custom House offices give on this point very precise information. Exterior events have had a great influence on the exportation of coke from this country. Whereas, in 1870 (the first six months having given brilliant results, and during the second half-year a new market—Germany—having been opened) the exportation amounts to 42 per cent. of the general production, it attained but 36 per cent. during the year 1871. In 1872, it rises to 45 per cent., and in 1873 it will be 50 per cent. of the general production.

It is most interesting to follow these considerable quantities running in form of regular currents towards the different markets of other countries; to see the sale in each direction increase or decrease according to political and economical circumstances; to see particular currents, owing to slight modifications in the conditions of transport, change their line of direction to arrive at the same destination; and, finally, to see others compelled by competition to take totally opposite directions towards new openings or markets. It is thus that the current of exportation towards the East

—that is to say, towards Germany, and particularly towards the Grand Duchy of Luxembourg—has increased from 1870 to 1871, while the one towards France decreased to the amount of 100,000 tons during the same period. In 1872, the consumption of coke in the Zollverein and France has been equal, and amounts to about 320,000 tons for each; and it seems this proportion will maintain itself during the present year; but it is very probable that for the year 1874 the proportion will no more exist, as the consumption of the Duchy of Luxembourg and of Alsace-Lorraine will far exceed the consumption of France.

The following table will show that the exportation of coke to other countries is not considerable :—

Destination.	1870. Belgian Tons.	1871. Belgian Tons.	1872. Belgian Tons.	1873. Belgian Tons.
Zollverein	215,660 ...	246,170 ...	370,235 ...	485,244
Netherlands ...	1,337 ...	2,887 ...	3,241 ...	1,860
France...	359,144 ...	258,112 ...	372,893 ...	432,924
Other destinations	360 ...	1,011 ...	2,050 ...	792
	576,501	508,180	748,419	920,820

According to the results obtained during the first five months of this year, we foresee a total annual exportation of 920,820 tons. It represents 50 per cent. of the general production. The exportation of 1872 represents 45 per cent. of the general production; there is, therefore, only a relative increase of 5 per cent. for the year 1873.

CONSUMPTION OF COKE IN BELGIUM.

The consumption of coke in Belgium is increasing gradually, and did not cease to increase from 1870 to 1871. This fact shows how solid are the bases upon which this national industry depends. The important markets of France were closed to her for a whole year, without affecting in the least the general development of its production and sale of coke. She knows, equally, how to profit by happy events, for we find her increasing her consumption of coke to 100,000 tons in 1872, and still increasing it this year. The comparison of the commercial movement of coke and that of coal

in Belgium gives rise to the following remarkable fact: the consumption of coal in Belgium is increasing daily, and promises within a few years to absorb the whole production, whereas, as concerns coke, it is the exportation that tends to take the prominent part; it will attain this year 50 per cent. of the general production. Belgian capital has been largely invested in the metallurgical enterprises of the Duchies of Luxembourg and Lorraine, so one may say that we feed Belgian industry in exporting our coke and coal to those great markets of consumption. The following table will give, *en résumé*, the general facts given in this notice:—

COMMERCIAL MOVEMENT OF COKE.

	1870. Belgian Tons.	1871. Belgian Tons.	1872. Belgian Tons.	1873. Belgian Tons.
Production ...	1,374,539 ...	1,314,915 ...	1,644,712 ...	1,838,096
Importation ...	8,108 ...	3,193 ...	8,101 ...	38,652
Total	1,382,647 ...	1,318,108 ...	1,652,813 ...	1,876,748
Exportation ...	576,501 ...	508,180 ...	748,419 ...	920,820
Remains for Belgian consumption	806,146 ...	809,928 ...	904,394 ...	955,928

In the actual state of industrial statistics in Belgium, the course we have followed for establishing the consumption is the one which presents the best guarantee.

APPENDIX.

GENERAL LIST OF COKE MANUFACTURERS IN BELGIUM.

NOTE.—The firms with an asterisk are those who gave no answer to our questions or those whose answers were considered insufficient.

MONS BASIN.

1 The Longterne-Ferrand Coal Company, at Elouges.
2 The Levant d'Elouges Coal Company, at Elouges.
3 The Grand Bouillon Coal Company, at Dour.
4 The Coal Company des Chevalières, at Dour.
5 The Coal Company Grande Machine à Feu, at Dour.

6 The Coal Company West of Mons, at Boussu.
7 The Coal Company Belges, at Frameries.
8 The Coal Company, Crachet-Picquery, at Frameries.
9 G. Panaux and Co., Bonne Esperance, at Wasmes.
10 The Seize Actions Company, at Quaregnon
11 B. Lupant and Co., at Frameries.
12 The De Produits Coal Company, at Flenu.
13 The Bernissart Coal Company, near Blaton.
14 M. Catelineau, at St. Ghislain.
*15 The Company of Transports de St. Dizier, at Frameries.

CENTRE BASIN.

16 The Serepy-Bracquegnits Coal Company, at Bracquegnies.
*17 The Bois du Luc, at Houdeng.
18 La Louviere and La Paix, at La Louviere.
*19 The Houssu, at Houssu.
20 M. E. Coppee, at Haine St. Pierre.
21 Cambier and Co., at La Louviere.
*22 Metz and Co., at La Louviere.

CHARLEROI BASIN.

23 The Monceau Fontaine and Martinet Company.
24 Mineur, Sons, and Wilmot, at Marchienne au Pont.
25 The Forges d'Acoz Company, at Acoz.
26 The Marcinelle Metallurgical Co., at Marcinelle.
27 The Marcinelle and Couillet Co., at Couillet and Chatelineau.
28 Francois and Co., at Charleroi.
29 Blondiaux and Co., at Marcinelle and Thy-le-Chateau.
30 The Reunion Company, at Mont-sur-Marchienne.
*31 The Montigny sur Sambre Co.
32 The Bassins Houillers du Hainaut Co., at Chatelet.
*33 The Works of South Charleroi, at Charleroi.
*34 The Piéton-Centre Co., at Piéton.
*35 M. Legrain, at Marcinelle.

LIEGE BASIN.

36 The Vieille-Montagne Company (Baldaz-Lalore), at Flemalle.
37 The Marihaye, at Flemalle.
38 De Wendel and Co., at Seraing.

39 Diziere-Delcour, at Seraing.
40 The Esperance Company, at Seraing.
41 John Cockerill Company, at Seraing.
42 The Bassins Houillers du Hainaut Company, at Seraing.
43 Witry and Co., at Seraing.
45 Steinbach and Co., at Angleur.
46 The Grivegnée Company, at Grivegnée.
47 Godin-David, at Jemeppe.
48 Taskin, Londot and Co., Tilleur.
50 Braconnier and Co. (Horloz Company), at Tilleur.
51 The Val-Benoit and Grande Bar Company, at Tilleur.
52 Godin and Co., at Ans.
53 The Baron d'Adelsward du Prieuré, at Jemeppe.

On Wednesday afternoon the members visited the extensive works of Messrs. J. Cockerill and Co., at Seraing.

On the evening of the same day they were entertained by the members of the Belgian Reception Committee at a banquet in Liége.

THURSDAY, 21st AUGUST.

The President said the first paper on the list was that of Mr. Kamp, on winding apparatus. The translation of the paper had been distributed on the previous day, and the members had had an opportunity of seeing the apparatus itself at Seraing.

ON WINDING AND OTHER APPLIANCES FOR COAL MINING.

By M. WILLIAM KAMP, Chief Engineer at the Mines of John Cockerill and Co., Seraing.

Apart from proper arrangements for drainage, ventilation, and underground hauling, the two main branches of the general business at a coal mine in active operation are the following, namely, the cutting and removal of the coal from the bed formed for it by nature, and, secondly, its carriage to the pit bank. The cutting out of the coal is performed according to a great variety of methods, each adopted on account of its special fitness in the different coal measures. The engineer is bound to take into account the character and composition of the seams; their density and hardness; their position in respect of inclination; the degree to which fire-damp may be generated; and the nature and solidity of the roof of any given coal seam.

The whole of the above-named different conditions are apt to vary greatly, not only as between one basin or country and another, but as between seams appertaining to one and the same bed or pit. Consequently, a mining engineer must pursue his plans subject to such physical peculiarities of formation which leave him no choice between two different systems of mining.

The shape and form of the cuttings must depend upon local considerations. This will be readily admitted by an assembly of English engineers, in whose country there are as many different systems of mining as there are coal basins themselves. Perhaps this statement would be even more thoroughly understood and appreciated by the members of a Coal Institute than by those of

the Iron and Steel Institute. Anyhow, there will be no occasion to dwell at greater length upon the absence of the necessity for arguing in favour of the reasonableness of adopting special plans of mining for different pits. In point of fact, to enter upon the question would involve the writing of a treatise, which, from its extent, would be hardly in keeping with the due proportions of an account drawn up for the purpose of being read at a meeting where metal alone enjoys a right of citizenship, and at which the coal mining interest ventures to attend only in the guise of an intimate friend, admitted on sufferance. The only point I shall take leave to notice in passing, because it will come upon foreigners connected with industrial pursuits in the shape of a startling piece of news, is this, namely, that within the area of our Liége coal basin, in certain pits enjoying the reputation of being the most profitable in point of yield, the average daily output per hand engaged in the mine is from six to eight hectolitres, which is equal to $1\frac{1}{2}$ day's work per ton of coal won.

In England, where labour figures in the calculation as a factor less crushing, there are pits at which a ton of coal requires but one-fourth to one-fifth of a day's work ; and we may add that the last named fractions are being, and will be, most likely further reduced by means of mechanical appliances which it is sought to introduce in coal mining ; appliances the advantages of which our country is unfortunately doomed to renounce until tools and apparatus shall have been invented capable of easy adaptation to the wayward nature of our coal seams.

The point on which coal-producing countries can borrow of one another with advantage, and render mutual help by supplying information as to new arrangements and contrivances, is that relating to the working plant and appliances.

Belgian coalmasters, it may be mentioned, have already availed themselves of a new contrivance first introduced in England, namely, the bucket or sledge system coupled with a loose chain. As regards the lifting apparatus, although information has been exchanged with a tendency to progress, yet the old appliances have been retained. But after all this is the very department of mining which will, ere long, demand the special attention of engineers, calling for certain modifications imposed upon us by the ever increasing depth of the shafts.

Engaged in the working of mines, the shafts of which have already attained to considerable depths, I have been led to the investigation of the difficulties before us, and to an enquiry into the best plan for meeting the same, taking the economical and regular prosecution of mining work into account. The results of such enquiries I now submit to the opinion and judgment of the great representatives of industry. I reproduce them with some confidence, for my colleagues of Liége, to whom I have had occasion to communicate my ideas in this respect, have shown no disinclination to adopt them.

I shall divide this short paper, belonging exclusively to the domain of coal lifting operations, into two separate portions—the first treating of the winding gear; and the second, of the engine, and the uniformity of its performance.

It will hardly be necessary to direct attention to the fact that the patent relating to the use of buckets, and to the model of the fittings, dates from the month of April, 1872. The note describing the system of regenerating power as a means of equipoising the ropes, dates from the month of October of same year. If we observe with care the ropes in use in Belgium, we shall be struck with the disproportion existing between them and the actual load to be lifted. The cause of this disproportion will be found to depend upon the weight of the material or tackle used in bringing the coal to the pit bank. Our coal pits are very far from being supplied with a uniform lifting apparatus. In point of fact, there exists just as many different cages and tubs as there are mines. What they all have in common, however, is a weight as inordinate as it is embarrassing and useless. In France and Germany there are very nearly similar appliances in use at this very day. As for Great Britain, not having visited the mining districts in that country for several years past, I cannot say whether or not any novelties in respect of said appliances have been introduced. Be this as it may, it is generally admitted that there exists a want of harmony between the receptacle and its contents all the world over, and that such a state of things brings about consequences progressively embarrassing.

I will now give the weights of trolly and cage as taken at the principal mines in Belgium, the figures representing upon an average the tackle and plant used in mines of from 4 to 500 metres

deep. A specification of working plant and fittings generally contemplates the following, viz.:—

Cage and tubs	2,400 kilogs.
Load of coal	2,160 „
Total	4,560 kilogs.

Three neighbouring pits, now in operation, supply the following, viz.:—

	Dead Weight.	Weight of Load.
A	1,736	1,440
B	1,607	1,080
C	1,900	1,500
	5,243	4,020
The average being	1,748 kilogs. ...	1,340 kilogs.

An extensive coal pit in the Hainaut district, recently started, has reached the following figures, viz.:—

Cages and trollies	2,360 kilogs.
Coal	2,100 „
Total	4,460 kilogs.

In Germany, the amount of the dead weight is not less exaggerated. A Saxon coal pit, having reached down to a depth of 804 metres, is provided with plant and fittings weighing in

Cages and trollies	3,782 kilogs.
The coal lifted being...	2,000 „

Everywhere, the dead weight is in excess of that of the load.

In order to show as clearly as possible the disadvantages attendant on the use of heavy machinery, let us ascertain the dimensions of thickness and width of a flat cable made of wild aloës fibre, intended to lift 24 hectolitres, or one cart load of coal, from a depth of 800 metres; and for this purpose we shall adopt the weights of the regulation lifting machinery above-mentioned, and which are relatively moderate, namely,

Cages and tubs	2,400 kilogs.
Coal	2,160 „
Total ...	4,560 kilogs.

Let us further suppose—

1st. That the cable sustains 80 kilogs. per sectional square centimetre.

2nd. That in a longitudinal direction, there are 4 decreasing sections, each of 200 metres.

3rd. That the cable is composed of six warps.

The weight of such a cable and of its cross sections will be as follows, namely:—

First Section	...	$\frac{180}{41}$ Millimetres	...	1,324	kilogs.
Second „	...	$\frac{203}{46\cdot6}$ „	...	1,708	„
Third „	...	$\frac{201}{53\cdot8}$ „	...	2,204	„
Fourth „	...	$\frac{262}{60}$ „	...	2,844	„
		Total	...	8,080	kilogs.

The above calculation establishes that for every 2,160 kilogs. of working load, the upper portion of the cable will have to sustain a weight amounting in all to 12,640 kilogs.

But I have just shown that the weight of the cable represents two-thirds of the total weight; therefore it is right to call attention to the fact that I have not taken into account, in the above calculation, the damp which will penetrate into the aloes fibre, for we are bound to assume that there are, at all times, infiltrations in the shafts saturating the lowermost portion; and wishing to ascertain the liability to absorption in aloes fibre, I caused a cable made of such material, and not protected with tar, to be completely immersed in water, the result being that it sucked up over 30 per cent. of water. Consequently it will be prudent to take into account an increase of weight arising from the saturation of the cables by water.

The objectionable nature of big cables is so well established that some coal masters have resolved to fall back upon the old system of small loads, with a view to compensate for the quantity by rapidity of deliveries.

To arrive at a correct conclusion in relation to the point now under discussion, it would be advisable perhaps to enquire whether the system of raising coal to the pit bank now obtaining, and which may be adapted for depths of from 300 to 500 metres, is quite as profitable in respect of greater depths.

Such an investigation might probably lead to this notable result, namely, the resumption of that old form of winding machinery and lifting apparatus, discarded once upon a time in the interests of progress, as it was thought, and known by the name of the corb or bucket system.

What we are, therefore, called upon to determine is the following question, namely—Whether it be not of the greatest urgency to reduce within the bounds of possibility the proportion of dead weight, even though this should involve a regular transformation, provided always that the change did bring about a substitution of receptacles specially constructed, the solidity and weight of which shall be in exact keeping with the requirements of the carriage proper of coals to the surface, in the room of the heavy lumbering cages and tubs now in use.

As a solution to the foregoing question, I now submit the following calculation, which determines the weight of a cable working under the same conditions as those described above, with this difference only, that in lieu of the weight of 2,400 kilogs. representing cages and tubs, I shall substitute a corb or bucket of equal carrying capacity, but weighing no more than 500 kilogs. The weight of the lower extremity of the cable will be as follows:—

Coal	2,160	kilogs.
Corb or bucket	500	„
Total weight	2,660	kilogs.

The above cable used in lifting from a depth of 800 metres will have the following dimensions and weights, viz.:—

First section ...	136.	7/31	millimetres,	772 kilogs.
Second „ ...	155.	2/35	„	995 „
Third „ ...	176.	4/40	„	1,285 „
Fourth „ ...	208.	3/45	„	1,657 „
				4,709 kilogs.

Consequently, bearing the same working trace of 2,160 kilogs., the upper part of the cables will have to sustain no more than 7,369 kilogs. of gross weight, whereas under the system now in use the said gross weight amounts to 12,640 kilogs.

It will be noticed that in the last named system the cable weighs 3,371 kilogs. additional, being an excess exclusively referable

to the 1,900 kilogs. of difference in the weights of the cages and trollies, as compared with those of the corbs or buckets.

But if, as is most likely, round-shaped steel cables of the kind, the use of which seems to be gradually extending both in England and Germany, be adopted, the desirability of diminishing the dead-weight will be just as great. These cables are wound round drums without overlapping, so that the serviceable length of the drum is proportionate to its diameter, to the number of revolutions, or, in other words, the depth of the mine, and to the thickness of the cable.

Now, let us see what result is arrived at if we take the weights assumed in the calculation made with reference to the Aloes cables.

The manufacturers of the two neighbouring countries are disagreed as to the practical power of resistance of steel wire ropes. We may remark here that the power of resistance will depend upon the description of the fittings, and more particularly upon the shape and position of the drums and pulleys.

As the arrangement of machinery is not everywhere identical, it follows that observations made respecting the durability of cables have led to the choice of sections widely different for each given strain.

On the one hand, English manufacturers (coalmasters?) put a strain of 7·7 kilogs. to 12 kilogs. upon every millimetre of the gross section of the cable; while, on the other hand, the Germans do not allow more than about 4 kilogs. to bear upon said section.

If we take the lesser of the two English figures, namely, $7\frac{7}{10}$ths kilogs. per sectional millimetre, we shall obtain the following results, viz.:—

FIRST EXAMPLE.

Cage and trollies	2,400 kilogs.
Coal	2,160 „
800 metres of cable, 35 millimetres in diameter, weighing 3·64 kilogs. per running metre	2,912 „
Total weight	7,472 kilogs.

$\frac{7472}{962} = 7{\cdot}76$ kilogs. per millimetre.

SECOND EXAMPLE.

Corb	500 kilogs.
Coal	2,160 „
800 metres of cable, $27\frac{4}{10}$ millimetres in diameter, and weighing 2·23 kilogs. per running metre	1,784 „
Total weight	4,444 kilogs.

$\frac{4444}{589}=7{\cdot}54$ kilogrammes per millimetre.

With a drum measuring seven metres in diameter, one of these cables will require a winding length of 1,295, and the second 1,014.

Now, the great length of drum thus rendered necessary is attended with two serious disadvantages, namely, the obliquity of traction which strains and wears the cable; and, secondly, the inordinate length of the shaft, which the constructor has a great interest in avoiding.

It will be needless here to enquire into the relative weight and resisting power of a flat metallic cable, for the proportions would be very nearly the same. Whatever be the kind of cables used, the main causes of their destruction are the initial efforts required for every renewal of the act of hoisting, and the strain put upon them by the necessity for overcoming the *vis inertiæ.* Nothing more clearly demonstrates this kind of wear and tear than the lengthening that occurs at every renewal of the first lift, and in this respect also there exist very powerful motives in favor of diminishing this bulk, which, in the ordinary course of things, must be set in motion hundreds of times during the day.

For all these reasons we shall be quite correct, undoubtedly, in asserting that the system of specially constructed receptacles will obtain in the future. It now remains for me to submit some details explaining the process of putting on the load at the bottom and taking the same away at the pit mouth; and to show that the use of corbs will create less trouble, cause less expense in wages than the transfer of the trollies into or from the cages. We have now come to the consideration of the most important point, let it be borne in mind, and this point deserves to engage the best attention of coalmasters.

The most approved system of hoisting will, of course, be that which combines rapidity of execution with the smallest effort, and the least labour, while enjoying the greatest immunity from liability to accidents.

I am of opinion that the corbs will, to a very high degree, fulfil the conditions above stated. Let us examine in detail the working of the two systems.

With the cages containing almost in all pits several trollies one overlying the other, the work is done in two different ways.

In the one case there is a double hooking on, and, if so, the cage yields up and receives without changing place and at one and the same time—but at the cost of employing double the number of hands—the trollies above and below. We know that the trollies intended for the nether compartment must first be taken to a lower landing or stage, and that for this purpose scales or inclined planes are used, both which appliances, of course, add to the requirements of the working plant, tend to the enlargement of the openings in the neighbourhood of the shaft, and very sensibly enhance the expense of labour; and as the same means are used for changing the trollies on the bank, accumulations at this stage of the work are likewise inevitable, and call for extra labour.

In the other case, where there is only one landing for fastening and receiving, the method pursued consists in working with the help of the hoisting engine, and in bringing each stage of the cage on a level with the point of fastening. This plan occasions loss of time, and offers the two-fold disadvantage of compelling the engine-man to repeat his work, and of straining the cables. It becomes troublesome, more especially, when the cables wind round spindles of unequal radius.

We are, therefore, entitled to conclude that the system in use is not without its drawbacks. Engineers have introduced the most ingenious improvements, it is true; but the objections to it have not been thereby removed.

Before entering upon a description of the working of the corbs, I shall ask permission to submit details as to their construction from a model I made and used in my first trials.

A Is the corb.
B B Semi-circular door.
C Iron stem with bifurcation at lower extremity, and connected above with the ring caught up by the cable.
D D D D Slides of guides.
E Bar of guides.
F Movable channel, serving as reception brackets at the surface.
G. Gilter fitted to fastening chamber at bottom.
H Inclined trough having a capacity equal to load of corb.

At the bottom of the shaft the filling of a corb capable of holding from 20 to 30 hectolitres can be effected in the simplest possible way.

The full load of a corb is got ready in the trough H; at the moment when the empty corb has effected its descent, and takes up its position near the place of fastening, the attendant, using a lever or chain, lowers the delivery valve, and the latter, in its new position, forming a channel, shoots the coal into the corb.

Examples of this mode of decanting are numerous at pits, both at the surface and below. Consequently we are not dealing, in this instance, with a novelty. As regards the discharge at the surface, it is effected in the following manner:

So soon as the corb has come up to the requisite height, the channel F is led back to the axis of the shaft, and serves as a purchase for the slides DDDD; the cable becomes slack, and no longer sustaining the delivery valves or doors BB, the latter give way under the weight of the coal, which falls and slides forward, taking up its position either in a waggon or dropping upon a screen, if any be set up in close proximity to the shaft.

There can be no doubt that this mode of proceeding saves time and labour, for the loading and unloading takes place simultaneously and mechanically, while at each end of the work the services of one attendant only are needed, and with certain mechanical appliances, even his services might be dispensed with.

Of course, I do not put forth the above arrangement as having achieved perfection, for I am quite sensible that experience will enable others to improve it in point of details.

It now behoves me to consider what objections may be brought

against this plan, and I quite anticipate it will be found fault with on account of the decantings it involves. I am aware that to this decanting or shooting of the coal is generally attributed the destruction of the large lumps. But, after all, the evil apprehended is but of secondary importance when viewed in relation to the other advantages of the system.

If we consider the sliding and sinking that occurs in the troughs, fitted with sheet iron bottoms, and used at pit banks, we shall have no difficulty in admitting that the heavy coal undergoes but little fracture. Moreover, let me remind you, that in the Seraing basin—just as in all centres of production yielding fatty coal for the manufacture of coke—the proportion of smalls is so large that the big lumps are but little exposed to the injurious effects of bumping, amongst themselves, in their fall.

As regards the preservation of the materials in use, and the maintainance in good repair of the several component parts of the machinery, I may be permitted to point out that all essential parts are protected against violent collisions by means of the annular shield surrounding the stem, and by the cross bar that secures the several parts.

But, if in the long run, one piece or other were injured and became unserviceable, it might very easily be replaced. The inconvenience and trouble to be guarded against seems to me smaller in degree than those arising from the use of cages and the mechanical apparatus they involve.

We may here just glance at another advantage which the system now recommended admits of, namely, the adaptation of a slight stop to the handle of suspension, which would, in case of breakage in the cable, be of the most remarkable efficacy, for, in point of fact, the claws would need to clutch and hold up no more than the weight of the corb, together with that of whatever portion of the cable might have been carried away. The coal would be precipitated, without causing any serious inconvenience, into the shaft, through the enforced aperture at the bottom. Whereas, when heavy cages and trollies are used, their weight, added to that of the load of coal itself, would cause the most disastrous consequences in the event of the rupture of the cable. The fall of an angular shape within the shaft will damage the wooden lining. This danger is more especially to be apprehended in shafts that are

badly masked; and instances of the scaffoldings being destroyed are not rare.

By using the corbs these dangers will be avoided. I do not wish to lay much stress on the possibility of the escape of the load which, however, will be sure to take place whenever the limbs of the stop come in contact with any projection; but I have no doubt it will be readily conceded that, in the event of an accident occurring, the light vehicle will cause less damage for one thing; secondly, that owing to its shape, it will just merely graze the wood linings; and thirdly, that the money loss resulting from the damage inflicted upon cage and trollies in case of a drop, will be much heavier than if such an accident happens when corbs are being used, although accidents rarely befall cables in well managed pits, yet we must not quite overlook such a contingency, nor refuse to assign considerable value to implements and mechanical appliances, that may contribute to attenuate the evil consequences of any such mishap.

I shall now proceed to the discussion of the second division of this paper, namely, the weight of the cables in its relation to the moments of resistance.

The constancy of the moment of resistance is just as favourable to the proper working of the hoisting engine, as the great winding *radii* of the cables are of use for their preservation. And there is a third proposition deducible from the principles just laid down, which is this, that as the winding radius increases, so the section and weight of the cables may be diminished.

Whether we use flat hempen, or flat metallic cables coiling upon themselves over spindles, or round cables wound round drums, cylinder or cone-shaped, their durability and resistance will be improved by the widening of the kernel that determines their transverse flexion.

Whenever a depth of shaft, measuring from 600 to 800 metres, has been reached, it becomes a difficult matter to obtain a moment of resistance that shall be tolerably constant during the whole period of the ascent, unless the initial coiling of the cable be effected over a kernal (stock?) of a radius so small as to militate against the conditions essential to the interests of proper maintenance and preservation. Compelling a cable, five centimetres thick, to coil itself over a spindle, three metres in diameter, while

the strain of the traction movement is making demands upon its elasticity, is, undoubtedly, exposing the same to a speedy destruction, owing to the effects upon it of transverse torsion, for the outer circumference of a coil undergoes a most extraordinary elongation.

If, as an instance in point, we take a cable five centimetres thick, and roll it round a stock having a diameter of three metres, we shall find that the outer face of the circle described will be 31 centimetres longer than the inner face, or $\frac{31}{957}=33$ millimetres per running metre.

Now, if the wear and tear consequent upon similar changes affects hempen cables injuriously, it must of necessity endanger to a greater extent the stability of metallic cables which possess a lower degree of elasticity. In the case of depths approaching 600 metres or more in extent, one is generally driven to abandon the idea of obtaining constancy of motion; and, since the dead-weights can no longer be equipoised, the result is that the engine is called upon to perform an excessive amount of work at the first start and lift, whereas, before the top is reached the momentum often becomes negative, that is to say, that the descending dead-weight will be sufficient in itself to effect the lifting off and ascension of the load of coal at a speed accelerated and so abnormal that, as a rule, it is necessary to let out the counter steam, and thus create an artificial resistance in order to bring it back again within the bounds harmonising with the principles of ordinary practice. Not only have we here a source of danger but an increased consumption of steam, into the bargain; which last is enough to cause us to regard the above named *modus operandi* as an expedient that calls for the prompt application of a remedy.

Besides the necessity for the development of power at the moment of lifting off, to a degree far in excess of what it ought to be upon an average, obliges us to give to the hoisting machinery in all its parts, such dimensions as are utterly out of proportion to the actual amount of work really performed during the entire extent of the ascension.

When round metallic cables are used, there is an arrangement of conical or cylindrical drums of greater or lesser diameter for the purpose of gathering up the coils. If these drums be conical, it must be admitted that, within certain limits, the constancy of resistance may be almost obtained, but in cases where the depth

is great they will need to be made of inordinate length, in order to gather up the succession of cable coils that keep winding round and round.

The result is an objectionable obliquity in the cables with reference to the axis of the shaft and of the top blocks, besides many other bewildering difficulties of construction. As regards heavy loads, coupled with great depths, it would even appear as though under present arrangements, we were struggling against an impossibility. Let us add that as the lifting of the load from the ground takes place at a time when the cable covers the drum following the small radius, this gives another of the causes of rapid wear and tear.

With cylindrical drums there is no apparent equilibrium obtainable for the *radii* remain constant on all hands. About the top portion of the ascension, the cage with the load of coal is pulled by the weight of the cage and descending cable. We must have recourse to a check or to the counter steam, and the drawbacks previously described will be exemplified in this case even with greater force. In order to remedy the evils resulting from want of equilibrium, and interfering both with the work and due economy, some parties have been induced to set up counter weights in special shafts, such counter weights consisting of chains coiling round drums, &c., &c.

Without going into the question of the very great expense entailed by the introduction of such appliances, it will be sufficient here to point out the self-evident fact, that the objections against them *per se*, and the dangers to which they may give rise, are good reasons why their employment should be restricted to certain special cases only, consequently, this is no way out of the difficulty. We have endeavoured to arrive at a solution of this question, the chief difficulties of which we have just explained, by instituting experiments with a view to test the working of various principles, setting completely on one side, every consideration respecting equilibrium and the constancy of the moment of resistance. And to this end we have invented a reservoir, or store house of power, made to collect the work developed in excess, when the descending cable effects the ascent of the load, and to restore again the power stored up when it becomes necessary to lift a fresh load.

These results may be obtained by pressing into the service an

hydraulic accumulator, or even a compressed air reservoir. Whatever be the system of engine used, whether horizontal or vertical, we make use of two special pumps worked either by a separate rod and crank, or by a simple prolongation of the piston rod. The two pumps must be fitted with an arrangement for a two-fold distribution of water (or air) allowing the same to pass on to an hydraulic (or other) accumulator of any kind that may be deemed most suitable—and upon the well-known principle of which we need not here dwell at length—then to issue forth from this accumulator for the purpose of acting in the capacity of a motive power upon the piston of the pumps above named. In some cases, even, it will be sufficient to fit up a single pump or cylinder connecting the reservoir or accumulator, whereby matters will be still further simplified.

Thus, the same water is the agent that on the one hand produces, according to the requirements of the case, a resisting force, checking the engine when it becomes overpowering—and on the other hand, an auxiliary power backing up the engine when a maximum of work has to be performed. The divers alterations of action will be evidently produced with much instantaneousness by the engineman's management of the reversing motion bar, or by means of any analogous action. In point of fact, the hydraulic power constantly stored up admits of the performance of all those movements which, under present arrangements, call for the development of an exceptional muscular effort, by the aid of light mechanical appliances contrived to utilise the action of said store of power exclusively. Nothing, however, has been altered in respect of the constitution of the hoisting machinery.

The reservoirs, or accumulators, must be so constructed as to be capable of collecting all the power put forth, in excess from the moment when the action of the steam becomes useless for the purposes of the ascension; no matter what the extent and rapidity of production of said power—which will periodically vary—may be at any given time. We may mention that the two barrels of the pump are to act in such fashion, also, that any single cable work in the shaft will be rendered easy without necessitating the use of steam cylinders excessively large in diameter.

Under present arrangements, in order to provide a means for picking up a rope dropped down to the bottom of the shaft,

diameters of cylinders have to be adopted very much greater than there is any necessity for, so far as the actual and regular work of hoisting up the coal is concerned.

If at any time it should become necessary to make exceptional exertions, nothing more would have to be done than simply to fill the accumulator more completely by causing a special small pump to act upon it; and the action of the water would, in such case, be an assistance to the steam in working heavy loads in the shaft at that slow rate of speed which alone is advisable under such circumstances. The adoption of the principles just enunciated, and their application by the use of the means we have described will allow, henceforth, of rolling very thick hempen cables round spindles having a diameter always in keeping with the thickness of the cables, and capable of insuring a long period of preservation in a state of thorough repair, resulting from the diminution of wear and tear connected with the spreading out cross-wise.

Moreover, in the case of metallic cables, we shall no longer need to have recourse to the conical drums, while the use of cylindrical drums, having a large diameter, will become possible in respect of great depths, since the mechanical working power of the descending cable may be gathered in at each ascension, whenever required, and subsequently utilized over again.

The President would be glad to hear any observations if any gentleman wished to make any on the paper; if not, he would suggest the propriety of thanking Mr. Kamp for the great trouble he had taken in reference to that matter, which was necessarily one of very great importance to them at the present time, when the world was beginning to be afraid of running out of coal; of course, any subject that bore upon the possibility of extracting coal from greater depths was one of very great interest to the world at large, and to the iron-making interest in particular.

The President then called upon Major Beaumont to read his paper.

THE DIAMOND ROCK-BORING DRILL.

By MAJOR BEAUMONT, R.E., M.P.

All new applications of machinery must, in these times of high-priced manual labour, have a peculiar interest, especially to such a body of practical gentlemen as that which I now have the honour to address; and the application of the diamond to the general purposes of mining will, I think, be allowed to be producing results well worthy of your attention. I appreciate fully the value of time, and shall, therefore, proceed at once to my subject, without making any introductory remarks, or referring to other means of doing the same work as is done by the Diamond Drill, except so far as may be necessary to explain the difficulties which it is asserted the system under discussion overcomes. The patents for the Diamond Drill are extensively worked by the Diamond Rock-Boring Company, the results previously obtained having removed the system from the category of experiment, and established it as a recognised and practical success. As a rule, the Company neither sell machines nor let them out on royalty, but contract, at a fixed price, for the execution of work. The business taken up by the Company divides itself into four classes, in some of which a greater advance has been made than in others.

1. The sinking of bore holes for the purpose of testing or prospecting for minerals.
2. The driving of drifts, galleries, and tunnels, whether for mining, waterworks, or railways.
3. The sinking of shafts.
4. The removal of subaqueous rocks by blasting.

All of you will have a general idea of how these operations are carried on. Still, in order to enable you to value the results obtained with the Diamond Drill, I shall recall the leading features of the position in which the application of machinery stands with reference to them.

1. Bore holes are ordinarily put down by giving a reciprocating motion to a chisel attached to the end of rods, lengthened as the hole is deepened, the *debris* being brought up by means of shells or augurs. This reciprocating motion is given either by manual labour or by power. A considerable difficulty and risk attends giving even a very moderately rapid reciprocating motion to a long column of rods, and to get over this difficulty, and facilitate their withdrawal, Messrs. Mather and Platt have constructed machinery whereby the cutting is done by the fall of a tool suspended from a rope, the great point of gain being the speed at which the necessary tools either for cutting or removing the *debris* can be lowered to their work and withdrawn. Attempts have, moreover, been made to apply a rotatory motion to steel cutters, but even in soft rock the progress so obtained has been extremely slow, because no steel can be got which will withstand the abrading action of the rock.

2. Headings are ordinarily driven by drilling holes and blasting them. Machinery is applied to the drills, by attaching them to pistons, actuated by compressed air in cylinders, a supply of water to clear the *debris* and cool the tool being used. The air is distributed by a valve, or valves, driven by suitable mechanism, and a rotating motion is given to the tool to obviate its striking two blows in the same place. All the percussive systems of boring machines in actual use come under the above description, varying in the greater or less degree of mechanical skill with which the parts have been arranged.

Some machinery has been made which proposes to drive tunnels, at one operation, entirely by machinery, and without the use of powder; but, hitherto, so far as I know, only a few yards have been so driven experimentally.

3. Drills similar to those applied to tunnel driving have been used for shaft sinking, but only singly, and I have not heard of any case where the speed of the sinking has been notably increased.

4. The putting down of blast holes under water has always been considered a most difficult operation, because a blow cannot be struck under water, and I have never heard of machinery being applied in this direction at all. I saw, on the Suez Canal, rocks being removed by blasting, but the holes were put in by ordinary churn jumpers, worked from barges anchored in the stream.

The Diamond Drill is, in principle, quite distinct from any other system of holing rock, and works by rotation without striking a blow. Its action is rather that of abrading than cutting, and the effect is produced by the sheer difference in hardness between the diamond and the rock it is operating upon. There is really no comparison between the hardness of the diamond and that of ordinary rock. If a diamond be kept rotating against a piece of sandstone it would cut a hole, say a mile deep, before it was seriously worn. It will be seen at once that if this wonderful resisting power be properly taken advantage of, a machine can be constructed that will hole rock without striking blows. This enables machinery of the simplest and most ordinary character to be used, and thus avoids those special difficulties that the mechanic must face when he is driven to utilize a large power in the production of percussive action; moreover, machinery can be applied in places where a reciprocating motion, if admissible at all, would present peculiar difficulties—such as making a hole under water, or putting down deep holes where, from the circumstances of the case, the cutter must be at a great distance from the source of power.

The diamonds that are used are not valuable gems, but carbonate, a substance that till lately had no commercial value, and was first introduced for the purpose of cutting other diamonds. It comes from the Brazils in considerable quantities, and though it has not yet been discovered in the Cape diamond fields, it is more than probable that it exists there, and, indeed, wherever the diamond is found. You will see that its appearance is much like that of a piece of coal, or dull jet, and as unlike as it is possible to be to its brilliant sister, the ordinary diamond, though chemists tell us that the two are identical in composition. I presume that one is perfectly, the other imperfectly crystalized ; and, if so, it is no doubt this very imperfect crystalization that gives to carbonate its value for my purpose, as it has no, or next to no, cleavage, and consequently does not split up and break in the way that a diamond or piece of boart would do. This last substance, of which I hold a sample in my hand, is an impure diamond, and would seem to stand half-way between the brilliant and carbonate. According to the tables published in Ure's "Dictionary of Arts," the following are the different specific gravities and degrees of hardness of some of the hardest stones :—

Substance.	Hardness.	Sp. Gravity.
Diamond from Ormus	20	3·7
Pink diamond	19	8·4
Bluish and yellowish	19	3·3
Ruby	17	4·2
Pale ditto from Brazil	16	8·5
Deep blue sapphire	16	3·8
Ditto paler	17	3·8
Topaz	15	4·2
Whitish ditto	14	3·5
Emerald	12	2·8
Garnet	12	4·4
Agate	12	2·6
Onyx	12	2·6
Quartz	10	2·7

Now, as there is plenty of corundum or rubies and sapphires in the market at mere nominal values as compared with those of carbonate, I thought they could be advantageously used in place of the latter, if only their hardness, as compared with the diamond, was anything approaching that which the tables led me to look for. On trying, however, both sapphires and corundum, I found the above proportions altogether wrong in point of hardness: they were nowhere near carbonate. The trial that I put them to was as follows:—I set a piece of carbonate in a suitable holder, and held it against a grindstone: the carbonate turned the grindstone down. On trying the same experiment with the other minerals, the grindstone wore them down. I am of opinion, therefore, that the diamond stands, in point of hardness of resistance to abrasion (if the two are not synonymous terms), at an enormous difference in advance of any other known material in nature, and this seems a most remarkable fact.

The application of the diamond to rock-drilling is worked out as follows:—The stones are set in an annular ring, made of steel; they are fastened in by making holes as nearly as possible the size of the stones to be set, and then burying them, leaving projecting only the amount necessary to allow the water and *debris* of the cutting to pass; the metal is then drawn round the stone so as to close it on every side, and give as large a bearing surface as possible to resist the tendency of the stone to be forced out. I may here

say the loss from breakage and from the stones being torn out is far more serious than from wearing; in fact, with good stones having good broad running faces, the mere wear is quite trifling. A stone breaking out is always a cause of damage to the others. The crown so set is attached to the end of a steel tube and kept rotating against the rock at some 250 revolutions per minute. Water is supplied through the hollow of the bar, whence it passes under the cutting face of the crown to the surface of the hole between the side of the latter and the outside of the boring tubes; the diamonds are thereby kept cool, and the *debris* from the cutting is washed away. The crown has to be kept pressed forward with a force depending on the nature of the rock to be cut, varying from 400 lbs. to 800 lbs., when the cutting is done at speeds ranging from 2 in. to 4 in. per minute. Granite and the hardest limestones are readily cut at 2 in. to 3 in. per minute; sandstones at 4 in.; and quartz at 1 in. per minute. These speeds can be increased at pleasure, but I give them as representing the rates at which the drills are ordinarily run in practice.

On the table is a sample of pure emery, which was cut at the rate of 2 in. per minute, by a crown which I now hold in my hand; and which has bored through 6 in. of emery, ten feet of granite, and ninety-five feet of hard sandstone; you will see that it is, so far as the diamonds are concerned, almost as fit for work as ever. The emery was cut out of a block put under the drill for experimental purposes, merely to show how great is the cutting power of the diamond. No rock is met with in mining that approaches emery in hardness, and, indeed, it would be a most difficult operation getting a hole put in it without a Diamond Drill.

The cutters travelling in an annular ring, it follows that a solid core is produced, an arrangement, which, while it ensures a minimum of work being done to make a given-sized hole, affords evidence of the strata passed through, a fact which is invaluable for certain applications. Having explained the crown, and the way in which it cuts, I shall now describe the machinery for utilizing it. 1st.—For prospecting. The drawings on the wall show two views of a prospecting machine which are in all essential particulars the same as those now being used. The crown is screwed on to the end of steel tubes, which are successively lengthened as the hole is deepened, the bars pass through a quill, and are gripped by a

universal clutch, which causes them to turn. Set screws on the top of the quill, steady them centrally at their upper ends; the quill is attached to a cross head which slides between two vertical uprights, and weights are provided, working over pulleys by which the weight of the boring rods and cross head are either increased or balanced, when extreme depths of holes are reached. The water is supplied by a force pump passing to the hollow bars through the union at the top of the quill. The other gearing about the apparatus is for raising and lowering the rods by power. It consists of a crab, and the lifting is done by means of a chain or rope passing over a pulley attached to shear legs across the hole. Two descriptions of boring tubes are used, as shown by the sketch, one of which is more expensive than the other, but it is stronger, and at the same time being nearly flush on the outside there is less risk of the rods jamming in the hole. Suitable tackle is provided for recovering the tubes when they break, and their hollow form makes them peculiarly easy to get hold of. It very rarely happens that any are permanently lost. The usual plan for lifting them is a taper tap which enters into the hollow, when a few turns suffice to get a firm grip. The following table shows the dates on which some bore holes have been commenced and finished, and at this moment the Diamond Rock-Boring Company have over thirty machines either at work or about to commence, all of which are keeping fully up to the average of speed there shown.

I beg to read one among many certificates given, as I think that independent testimony of work actually done would be more satisfactory than any statement of mine :—

"Dundraw, Wigton, June 2nd, 1873.

"To Major Beaumont, R.E., M.P.

"Dear Sir,—I feel that I should not be doing my duty to the Diamond Rock-Boring Company, without adding my testimony as to the speed, excellency, and satisfactory manner with which your Prospecting Machine (No. 14) has done its work for me in Ireland. The Borehole at Ballycloghan was commenced on the 7th of April and completed on the 23rd of May, when a depth of 558½ feet was reached, the whole of which was bored through hard basalt and whinstone; during this time the machine was ordered to stop for a week for consultation with another gentleman as to the advisability of going

deeper; and, allowing for this, and also Sundays and wet days, the daily average was within an inch or two of 20 feet per day, and upon two days a depth of over 40 feet each day was bored at one time, and in the presence of myself and several other gentlemen, the machine was boring at the extraordinary speed of 3 inches per minute (whinstone.) An enormous quantity of core was daily extracted, and a complete section with perfect specimens was easily made. I may add I hope soon to require another machine or two to bore near here and in Scotland.

"I am, yours very truly,
(Signed) "R. A. WATSON, C.E."

STATEMENT SHOWING RESULTS OBTAINED IN SOME OF THE BORE-HOLES EXECUTED BY THE DIAMOND ROCK-BORING COMPANY.

Locality.	What for.	Including getting Machinery on the Ground, &c.		Actual Working Days.	Depth.	Remarks.
		Commenced.	Ended.			
		1872.	1872.		ft. n.	
Girrick	Ironstone	Oct. 1	Nov. 30	54	902 0	Ironstone.
Moorsholme	,,	June 1	July 27	48	641 0	Ironstone found.
			1873.			
Fishburne ..		Nov. 9	Feb. 1	54	434 0	Coal found.
		1873.				
Beeston	Coal	Feb. 22	July 22	146	1,008 0	Boring stopped on the 22nd July.
		1872.				
Chewton	,, ...	Dec. 31	July 13	168	802 0	Boring stopped, and commenced in another place.
		1873.				
Wollaton ...	,, ...	Feb. 16	April 12	48	700 0	Commenced boring at 387ft. below the surface of the ground. At 452ft. passed a seam of coal 1ft. thick; at 587ft. a seam 6in. thick; at 654ft. 6in. a seam 4ft. thick; at 696ft. through a seam 5ft. 10in. thick.
Loftus	Ironstone	Mar. 16	June 7	60	640 2	Ironstone found.
Ballymena.,	Coal	April 7	May 24	42	558 5	Nothing of value discovered.

The greatest speed attained was at Walluff, in Sweden, when 304ft. 6½in. were put down in one week.

In soft strata, such as clay, sand, and alluvial deposit, the diamond system is of no use, and in such ground we always use the ordinary method of boring, turning to the diamond directly rock is reached. I may add, however, that the boring tubes, pump for supplying

water, and the whole arrangement of prospecting machinery (irrespective of the diamond crown), is found of great use in getting through the soft, and fixing any necessary lining tubes. The actual speed of cut is the same as that previously quoted. There is, however, no advantage in cutting at so rapid a rate, as the time employed in actual boring is as nothing compared with that which is consumed in lifting and lowering the rods. Different distances are bored without lifting, according to the nature of the strata, and the necessity for obtaining information. The core, when formed, is passed into a core tube, and is kept from falling out on withdrawing the rods by means of sliding wedges or clips, which allow the core to pass freely up, but prevent its returning. The great advantage claimed for this system of boring consists in the speed obtained—work being done in less than months that formerly took years, and in the fact that sample cores of the strata passed through are obtained. To realise the benefits likely to accrue from these facts, one must remember the unsatisfactory evidence afforded by the powdered material brought up by the ordinary method.

Shafts have sometimes been put down in wrong places; and it is always of importance to know the strata to be sunk through, hence, I think, in future, few pits will be sunk without first accurately testing the ground by actual boring. Unless such a speed as the Diamond Drill gives were possible, this course could not be followed, as, though it might be well worth while to delay a sinking for a month or two for perfect information, it would be quite impossible to do so for the same number of years.

Turning to tunnel driving, you have before you a drill such as is actually used for that purpose, the leading features of which are that the drill shaft is screwed, and is driven by means of a longitudinal slot and feather. Gravity, as in the case of the prospecting machine, cannot be used; hence the advance is given by a nut driven by differential gearing. The feed would be positive were it not that the connection between the nut and the driver is by means of a friction break around the former. The break is held together by an adjustable spiral spring, and one of the lugs to which this spring is attached forms the driver of the nut ; hence, when the power necessary to drive the nut exceeds the compression at which the spring may be arbitrarily set, the break not only slips but is actually taken off the nut. This arrangement

has never failed in practice, and the drills may be relied upon with absolute certainty to relieve themselves whenever the pressure necessary to cut the rock exceeds a certain amount. Such an arrangement as this is necessary, since the rock is always variable in hardness. The drills, not being subject to the heavy blows which percussive action would throw upon them, are not more liable to deterioration than ordinary machinery. Some drills are now in good order, and at work, which were made three years ago, having since then cost next to nothing for repairs, Any number of drills that may be required are mounted on standards, which are connected with the air motor behind them, so as to be all driven from it. Each drill can be stopped and started independently, and as they work equally well, no matter how they may be angled, holes can be put in in positions where a miner would find it extremely difficult to work. The general arrangement of the company's tunnel-driving machinery is shown by drawings exhibited, and I would draw your particular attention to the method of fixing and removing the machinery. The jacks on the top of the standards fix the whole firmly in position, while on their being slackened and the standards tilted back, which is done by the machine itself, the whole is on wheels and free to move. Twenty minutes suffice ordinarily to get the machine ready for work, and it could be done in less time.

In applying machinery to driving headings, and speaking only of those machines that operate by holing the face of the heading, and use explosives, there are two broad systems of working, which have been followed. One is, to endeavour to imitate the action of the miner who seeks to put in his holes to the best advantage, watching each shot and angling the next accordingly, and putting down at the most three or four holes before firing. The other system is, to disregard the lay of the rock and the result of the previous firing, putting down such a number of holes as to make an absolute certainty of the rock being fetched to a given depth. All attempts to solve the question of tunnel-driving machinery by the first system seem to me to have failed, while the second, if fully applied, has always been successful. In practice, the principal difficulty consists in bringing forward and fixing the machinery, and its subsequent manipulation, and as all boring machines once fixed put down their holes in a very few minutes, it follows that

ease of management, and exemption from break-downs is a far more important element of success than mere rapidity of holing, which, indeed, all systems that I have seen possess. The following statement, taken from actual practice, will exemplify what I mean:—In a gallery driven in compact mountain limestone, by the Diamond Boring Company, as an advanced heading for a tunnel in connection with the Great Western and Midland Railways at Bristol, thirty to forty shots were required to bring away the face, the holes being 3 ft. 6 in. deep, and an advance each shift of about 3 ft. 3 in. being obtained. Six drills were employed, their average speed of holing being 2 in. per minute, 30 holes at 3 ft. 6 in.=105 ft. and six drills at 2 in. a minute=1 ft. per minute, or the complete holing was done in 105 minutes=1 hour 45 minutes, of actual working. As a matter of fact it was very good work to get the lot holed in four hours. Supposing now the drills had been speeded to 3 in. per minute, or 50 per cent quicker, the holing would have been done in a little over an hour, which would have shown a saving of only half-an-hour in four hours. My aim has therefore been to take a reasonable rate of speed like 2 in. per minute, and by so doing get certainty of obtaining a given result without break-downs, rather than trying for a *tour de force* in actual rate of cut. Exploding the holes is done successively, beginning with the central holes, which are angled, and progressing successively to the outside ones. At Mont Cenis, the length of their machines precluded the possibility of angling, hence they were driven to obtain a first opening by putting down larger holes in the centre of the heading, which were not fired. The Diamond Drill being shorter, enables the drills to be angled, and the centre is blown without the aid of empty holes. I think it likely this is the cheaper plan, but I am not clear that the Mont Cenis engineers did not choose the more expeditious one, as the fact of angling means a loss of progress.

In comparing the diamond system with the Mont Cenis or other good system of reciprocating drill, mounted in such numbers as to have a proper command of holing power, I do not contend that there is much advantage in favour of the former in point of speed, as in either case the holes can be put in in any reasonable fixed time. I submit, however, that there is a certain gain, owing to the holes being true cylinders, and to the non-liability of the drills to break down, the machinery getting out of order being always a

fearful source of delay. The great advantage claimed for the diamond system is its economy. No drills have to be sharpened, the plant is no more liable to get out of order than ordinary machinery, and the air in the motor can be used expansively, against which have to be set the wear of the diamonds, and the fact that the motor must be kept running whether one or six drills are at work. The latter disadvantages are, however, more than counterbalanced by the former advantages. The certificate of Mr. Brunlees, the engineer for the Bristol Tunnel, is as follows:—

"CLIFTON TUNNEL,

"WESTMINSTER, 13th May, 1872.

"To the Machine Tunnelling Company.

"Gentlemen,—Last week I had the pleasure of seeing your Diamond Borer at work in this tunnel.

"The material through which the tunnel is being made is hard mountain limestone, with numerous joints filled with calc spar.

"The heading, which measures about 10 ft. by 8 ft., was previously driven by hand labour at an average speed of 9½ ft. per week.

"The Boring Machine, during its first week of actual work, advanced the heading 26 ft., though the men only made eight shifts, the rate of progress per shift 3 ft. 3 in. The result of the week's work was, therefore, nearly three times that attained by hand labour, and it is only reasonable to assume that when the machinemen are fairly up to their work they will be able to bore 4 ft. per shift, and make twelve shifts per week.

"Hence there can be no reasonable doubt that the advance of the heading will become 48 ft. per week, or about five times that of hand labour.

"So far, the diamonds show no symptom of wear, nor have any of them got loose in the setting.

I am, Gentlemen, yours truly,

(Signed) "JAMES BRUNLEES."

SHAFT SINKING.

The plans on the wall show the plant which is now about to be applied to sinking two pits, each 700 yards deep, for Harris' Navigation Company, in South Wales. The shafts are not yet ready to receive the machinery, or it would long ere now have been at work.

It will be seen the principle is the same as that which obtains in the tunnel-driving machinery, viz., a pair of girders or standards carrying as many drills as can conveniently be put on, which latter are driven by a double cylinder compressed air engine, and each drill can be stopped and started singly. The system of working may be the same as that which I have described for tunnel driving, but as the Diamond Drill bores a hole equally well 100 as 1 ft. deep, it is in contemplation to apply a new principle which the different circumstances which obtain in a shaft, as compared with a heading, render practicable. In place of drilling a series of holes 3 ft. to 4 ft. deep, the holes will be carried, at one operation, say 100 ft. deep. The machinery will then be removed, and the blasting continued, until the whole depth bored has been reached. The anticipated advantages of this system are that the machinery will only require fixing once; and further (which is the main point), the operation of drilling can be carried on whether there is water in the shaft or not. Of course, 100 ft. is an arbitrary depth, and as the drill never gets out of truth, there is no reason why the holing 500 ft. deep should not be done from the surface, or so soon as the rock may have been reached. I quite anticipate that since the holes are all straight, or nearly so, it will occasionally happen that there will be no free side to blow to, or, in other words, the shaft will be fast, but in that case it will be easy to free it by putting in a few hand holes. I am given to understand that in America this system has been tried with very favourable results, and I hope shortly to test it fully. If successful, the enormous difficulty which dealing with water always presents will be materially lessened, and a considerable economy both of time and money will result in sinking shafts, as the most tedious part of the operation, namely, the holing, can be done by machinery from the surface and irrespective altogether of the question of water. I shall have much pleasure in communicating to any one in Belgium interested in the subject the results that may be obtained.

REMOVAL OF SUBAQUEOUS ROCK.

As regards the removal of subaqueous rocks, the drawings on the wall show the plant now being prepared to carry out a contract for the removal of rocks in the river Tees. The contract is between the Diamond Rock-Boring Company and the river Tees Commis-

sioners. The work to be done consists in the removal of a scarp of rock 600 yards long by 200 yards broad, with an average of 20 feet of water over it at high tide. The rock is a terrible bar to navigation; it cannot be got away except by blasting, and to hole it by hand from a fixed stage would be a most costly and laborious operation. The plant consists of a barge, supported on legs, adjustable to suit the irregularity of the bottom of the river. It is provided with an engine and boiler, capable of driving 24 drills. That number of holes can be quite easily put down in a tide, as each hole 8 feet deep will not take more than an hour to drill. The dynamite, which is the explosive to be used, will be introduced through the same tubes which guide the drills, and the holes will be exploded so soon as the barge has been shifted to a fresh scene of operation. The arrangements are such that the holes will be loaded and fired without the employment of divers. A single drill has already been used on the rock to prospect it, and a few shots fired, sufficient to show that the designed interval of 10 feet from centre to centre of the holes admits of the rock being sufficiently broken up for dredgers to remove it, and at the same time the action of the drill under water was seen to be perfect. I give a general sketch of the machinery used for prospecting under water, and which was specially designed to meet the case of a rough sea; the single pile offers no resistance to the waves, and the power required to drive the drill can be conveniently taken from a barge or tug alongside by means of steam through a flexible tube. The Diamond Rock-Boring Company are offering to undertake the removal of the Daunts Rock near Cork harbour, and other sunken rocks in seaways; and for this purpose the Diamond Drill is submitted to be unrivalled, owing to the fact of its working as well in water as in air, and its being independent of the distance at which the boring may be carried on from the machine itself. In the limits of such a paper as this it would be impossible to go more fully into detail than I have done. The whole and sole claim to merit on the part of the Diamond Rock Drill consists in the fact that the use of carbonate enables rotatory to be substituted for reciprocating motion. Percussive machinery must, from its nature, be expensive, and, in some cases, it is especially difficult, if not impossible, of application. I have not alluded to the use of compressed air in tunnel driving, which is common to any system; but I may be permitted to say

that the value of compressed air, as an adjunct to mining, is only now beginning to be properly recognised, and in proportion as it is introduced for underground winding, pumping, and other purposes, so it will facilitate the introduction of machinery for tunnel driving, as the compressing machinery necessary for setting drills in motion becomes a serious consideration when it has to be put down for that purpose only.

Mr. Steavenson had had the honour, two or three years ago, when in London, to be asked what his feeling was about driving a drift in Cleveland, and for that purpose using the rock-boring machine. It appeared to him at that time to be a machine which was useful in the main for working very hard stone or for very deep holes, and he then advised Major Beaumont that, as far as he could judge, the stone and rock in Cleveland was not such as would afford a suitable opportunity for employing his drill, it being very soft, and before he could even fix a large heavy machine like that, the material would be all to pieces. He (Mr. Steavenson) still thought that for very hard rocks, and tunnels—where a number of holes had to be driven at one place,—and for those alone, would that machine be found suitable for boring. He would be glad if Major Beaumont would point out to them how he managed in the event of his losing one of the diamonds in the head of the machine. He (Mr. S.) would like to point out one or two of the little weaknesses that had occurred to him, so that Major Beaumont might explain to them exactly the benefit of the invention, and how he overcame any little difficulties that he met with. The first and fourth heads were those under which it appeared to him it would be most useful, particularly for putting down holes in order to try hard rocks, and under that head he (Major B.) had not put it to them as he (Mr. Steavenson) thought he might take the liberty of doing, viz.:—That it afforded an opportunity of seeing the exact nature of the rock, which no other system of boring did. When they got out those cores—supposing they were passing through a seam of coal or ironstone—they could see at once whether it was good throughout—whether it was mixed with band, or in what condition it was; and he knew that already in Cleveland a depth of 600 feet had been bored in about three months, and the nature of the seam was shown in a

manner that was most valuable to those who wished to see the trial hole put down. There was another point to which he did not see that Major Beaumont had alluded. Instead of cutting out the hole, as was done in the old boring, he simply cut the circumference, thus having much less to do than with the common drill, and that enabled him to do the work with less labour. That was one great advantage, and one which he did not recollect hearing Major Beaumont mention in his paper.

Mr. Cockburn had the opportunity, a short time ago, of putting down one of the deep holes in Cleveland, by Captain Beaumont's machine, on a piece of ground that had not been proved before. They started the hole on the 8th of June, 1872—the depth was 641 feet—and they finished it on the 25th day of July, although they had been standing still for something like two weeks for want of water for driving the apparatus. Not more than a quarter of a mile from the hole where that machine was put down, he (Mr. Cockburn) started to bore a hole by hand on the 6th day of July 1871, and did not complete it until the 4th day of May, 1872, and he could safely say that the great difference between the hand boring and the machine tunnel boring was something that they could hardly fairly bring their minds to bear upon, for the simple reason that they could not get anything up out of the hole made by the old hand system of boring, but what was broken piece by piece into small dust, so that they then had very imperfect samples as the result of boring the holes, and more than that, they found great difficulty in boring holes of that description. If they got into a hard rock, they very frequently got chippings from amongst the debris, and the wearing of the chisels, which gave them a false impression of what they were raising as a whole, but on the other system they could get—as Mr. Steavenson said—borings that would show them the nature of the seam from end to end; they could, in fact, by the machine, get as complete a section as though they had the hole laid open before them, and it afforded him great pleasure to bear testimony to the expeditious and satisfactory way in which the Rock-Boring Company had done their work in Cleveland for Messrs. J. W. Pease and Co.

Major Beaumont said, with reference to the question that Mr. Steavenson asked, as to what he did when a diamond came out, he had only to say that he put another one in. The value of the

machine turned entirely on the question whether the loss of diamonds was or was not covered by the value of the work that was done. The Rock-Boring Company had now a very large amount of carbonate, and they were continually buying. Sometimes they would bore perhaps 400 or 500 feet and the stones were barely touched at all, and there would consequently be next to no loss, so that 500 feet would then be done at a sum considerably below what the tools could be sharpened for; then, they would come on to rock where pieces of quartz were mixed up with the stone, or they might come upon that which was the worst material they had to deal with, viz., a gravel conglomerate; the ground would suddenly pass from hard rock to soft, and *vice versa*, causing perhaps one stone to break, doing £7 or £8 worth of damage in a hundred revolutions; but if they averaged the total expenditure on diamonds, and compared that with the amount of work that was done, then—without absolutely mentioning an exact figure—he could say that the cost of the diamonds was well indeed within the value of the work that they did. With reference to the other point, that of tunnel driving in soft strata, there was no doubt that that system of boring would not, and could not, in his (Major Beaumont's) opinion, work advantageously; the harder the rock, the greater the proportion that the labour of putting down the holes bore to the whole work that had to be done. Thus, if they took the two extremes, they might get a heading—and there were plenty of such in the coal measures—where, without using a machine, it could be driven at the rate of 5, 6, or 7 yards in a week. Where that was the case, he doubted whether they could do more than double that rate, and that at an increased cost. Then another extreme was, where it was very hard, he (Major Beaumont) had known a gallery where they could only do 2 feet to 2 feet 6 inches in a week, and in such a rock they could do in one year what would otherwise take 6 or 7. Then if they took the more ordinary cases—for instance, what he called a gallery in hard rock—say one that could be driven at an average of 3 yards a-week, they would then bring that 3 yards up to five times that, and do at the rate of 15 yards a-week. When they came to the question of cost, it was a very difficult one to enter upon, and he did not intend to do it then; but he might say broadly that when they took into consideration the question of putting down the machinery,

and providing the power—taking into account also the various drawbacks to its use—they would find that machines could not drive headings as economically as they were driven by hand, and if they added to the cost the royalties that had to be paid for the machinery, they would see that the cost of driving headings by machinery was certainly in excess of that for which they could be driven by hand, that excess representing from $1\frac{3}{4}$ to twice as much. The point then to consider as to the application of machinery was this: Is the fact of being able to do in one year's time what would ordinarily take from four to six year's time, worth paying so much more for, or is it not? He (Major Beaumont) could quite understand that in many cases, where it was desirable to open a mine rapidly, it was worth the owner's while to pay double, but in similar kind of work, where time is not so important, it might not be to the owner's advantage to pay double. They would permit him to say that he hoped the time would shortly come when they would be able to offer to the mining world something that would drive headings as cheaply by machinery as could now be done by hand labour. It seemed to him that machinery was being applied in all branches very successfully, and that that particular branch, viz., driving galleries by machinery, was, unfortunately, the most behind-hand of all. With reference to the other question asked as to the annular form, he had, he thought touched upon it in his paper, but only very slightly, and after all—as they undertook to do the work—the question whether it required a little more, or a little less, power to drive the machine, was one that concerned the contractor rather than the employer of the machinery.

The President was sure that the gentlemen present would agree with him that the thanks of the meeting were pre-eminently due to his friend, Major Beaumont, for his excellent paper. The Major had very properly told them that the question dealt with in his paper was not merely a question of expense. Where they wished to ascertain truth, it was not so much a question of expense as it was of correctness of information. Time, too, in those matters was a question of very great importance. He (the President) himself had been so much impressed with that, that Major Beaumont's company was at present engaged near their own works in order to put down a hole of something like two hundred (200) fathoms deep to ascertain facts as to the existence of salt, and as the company

was just now commencing its operations, he hoped in a few weeks —certainly in two months, he expected to complete that hole of 200 fathoms. He (the President) was sure they would agree with him that they were indebted to Major Beaumont for the very lucid manner in which he had explained the character of the machinery, and, so far as he was personally concerned, he most sincerely—as he was sure they all did—wished him and his company every success.

[M. Martin followed with some observations upon the manufacture of steel by a direct process. These remarks will be printed later on in the JOURNAL.]

ON THE RISE AND PROGRESS OF THE IRON AND STEEL INDUSTRIES IN BELGIUM.

By M. JULIEN DEBY, C.E., Brussels.

A celebrated countryman of yours, Mr. Layard, whose researches have brought to light so many interesting facts in connection with the state of the arts and sciences of antiquity, has proved beyond a doubt, that at a period when both the Briton and the Belgian were little better than barbarians, the Assyrians and other eastern nations knew how to manufacture iron. Relics, 2,800 years old, are in existence to tell their own tale in this respect.

In those times of the "very long ago," the western inhabitants of Europe, few and far between, were hunters and herdsmen, and had never heard of either bronze or iron as materials for their rude tools and domestic utensils.

We are, however, very ignorant of the state of things in this country prior to the arrival of Julius Cæsar. Archælogical discoveries of quite recent date, still unpublished, seem to indicate that at the period of the great Roman conqueror's invasion, iron had already been made in Belgium, while it was yet unknown to the inhabitants of the British Islands. The oldest records we have consist in vast deposits of cinder which cover many acres of ground, and are situated at Niew Rhode, between Louvain and Aerschot, in Brabant, as well as at Tessenderloo, in the Antwerp *campine*, where they generally occupy the top of the many ferruginous hillocks of that region. The discovery of these relics is due to M. Piot, *sous archiviste* of the Government. Along with these accumulations of iron cinder are found flint arrow heads and fragments of coarse pottery, characteristic of the earliest dawn of civilization, and which must have belonged to the old pre-historic workers of these deposits.

At a later period, and during the Roman dominion, iron was produced in very many places in Belgium. Immense heaps of cinder are to this day scattered in many parts of the country, and several of these are being profitably worked in the neighbouring

blast furnaces. Houses are being pulled down, hills levelled, valleys dug up in pursuit of this precious waste of the ancients, this cinder being remarkably rich in iron.

The present inhabitants of the localities where these cinders are found call them *crayats* or *craihats de sarrasins,* or slag of the Saracens, this being a vague denomination which was applied to pagans in general, a race of which, of nomadic habits there can be little doubt, must have existed in those early days, whose business consisted in the working of iron.

Our simple peasantry attribute the existence of these cinders to the work of the *Nutons* in the Walloon country; to that of the *Alver* or *Halvermannikens* in the Flemish portion of our soil; both denominations being synonymous with *Elves* or *Fairies.*

A lucky circumstance has enabled us to gain an insight into the mode of manufacturing iron in these primitive ages. Two old furnaces yet filled with their contents were dug into in the year 1870 at Lustin, between Namur and Dinant, a full account of which has been published by M. Berchem.*

A simple oval excavation with a rounded bottom in a bed of clay, the long axis 12 feet, the short one 9 feet in length, with a depth in the middle of about 3 feet, the top being level with the surface of the surrounding soil, constituted the whole of this apparatus. A channel excavated in the clay, but covered over with slabs, conducted the wind into the lower portions of the furnace. The opening of this channel was turned in the direction of the prevailing wind, which alone no doubt was used as blast, so that iron could only have been made on windy days.

The *modus operandi* must have consisted in the piling up of successive layers of ore and wood, or perhaps of charcoal, until the vessel was filled up, and the erection on the top of an immense mound of wood. After a lengthened period of time the desired end of reducing oxide of iron into malleable iron, without passing through the intermediate state of pig metal, was effected.

The lower portion of the ball extracted from the Lustin furnaces, furnished, when analysed, 93·48 per cent. of iron, 0·37 of carbon, 4·94 of vitrifiable substances, and 1·21 of sulphur, phosphorus, and manganese. The middle portion still contained 35 to 40 per cent. of iron, along with silica, lime, and alumina.

* Copies of this notice were kindly offered to the members of the Institute by the author.

During the Roman dominion, iron was manufactured in many places, such as Mossée and Halloy, in the province of Namur, in the valley of the Bocq, near Dinant, in the region of Entre Sambre-et-Meúse, at Vodecee, at Kehlen, in Luxemburg, and many other spots. In all these localities, as well as in the ruins of Roman Villas, grindstones, pottery, and other antiquities are found, along with cinder and iron, which establish the period of their deposition.

From this time forward, until we come to the tenth century, little is known of the movements of our ironworks; but, concerning this period, documents exist which show a prosperous state of our iron trade, and assure us that permanent furnaces built of stone, and lined with clay, and elevated above the surface of the country had replaced the underground affairs of the earlier ages. The *fluss*, or *flossöffen*, had replaced the *stück*, or *wölfsöfen*, and remained in use for a long period afterwards.

In the twelfth century, iron was made to perfection in the Netherlands. In 1345, William, Count of Namur, granted great privileges to the workers of iron, and among them to the furnace of Dames, near Namur, which was in operation in 1340. Unfortunately, from the twelfth to the fifteenth centuries little more than political struggles and bloody wars are recorded by the historian, to the neglect of the nobler arts of peace. In 1468, all the works near this city of Liége were destroyed by the soldiery of Charles the Bold, of Burgundy; the city itself was sacked and burnt down, and no fewer than 40,000 of the inhabitants of the locality perished by the sword. This, as may be supposed, gave a momentary check to the industry of this enterprising race.

At the close of the fifteenth century, leather bellows were in use for driving the blast into the furnaces of the district of Liége. In 1560, no fewer than 35 blast furnaces, and 85 forges, were in operation throughout the country. In the year 1635, Philip the First granted special privileges to the ironmasters of Namur. We know that in 1693, a charcoal blast furnace required 110 labourers, including wood cutters and charcoal burners, that a finery needed 30 men, and a splitting mill 10. Empirism and simple practice were alone known until the middle of the eighteenth century, which corresponded with the end of alchemistry, all searchers for the philosopher's stone being at this period liable to imprisonment, or to the more unpleasant infliction of corporeal punishment, as is

shown by the edicts, dated 1731 and 1735. Towards the middle of the last century, charcoal became very scarce and expensive, just as it did in England, and in both countries experiments were made to replace its use by that of coal. On your side, Sturtevant and Dudley were the pioneers; on our side, the first trial on record was made in 1769, at Juslenville; the next was at Bouvignes, where Mr. Amand, in the year 1800, made 12 tons of excellent iron with coke alone, while other works used a mixture of coke and charcoal. In 1827, Octavius de Strada also proposed its use, but failed practically, as did most of those who tried the new fuel.

In 1784, Cort and Partnell published their process for converting pig iron into malleable iron in a reverberatory furnace, and the Abbe Needham, who was at this period director of the Brussels Academy of Sciences, made many interesting experiments on the same subject, full details of which are to be found in the memoirs of that learned institution. The great French Revolution soon after this period cast a gloom over Europe, and spread desolation throughout our mineral region. After peace and quietness were restored, things began, however, little by little to recover. In the year 1800, circular blast furnaces replaced the octagonal ones in use until that period, their height was raised at the same time from 15 to 25 feet, and to the then enormous product of three tons per day.

In 1817, John Cockerill, your great countryman, who is considered as the founder of the modern Belgian iron trade, started the works of Seraing, and in 1823 he erected the first genuine coke blast furnace in this district. In fact, until 1830, this remained the only coke furnace in the province.

In 1819, MM. Lejeune and Billard, at Fontain Leveque, created a sensation by the building of a double-acting steam engine, working to between three and four atmospheric pressures above the atmospheric.

Railroads and capital united now to promote industry in a young nation which had just then broken its bonds, and was inhaling the first refreshing breezes of its independence and free institutions. From the year 1830 until this day our iron industry has regularly increased in importance, and if we exclude a few dark years, such as 1839, 1843, and 1848, few nations can boast of such a rapid progress.

In 1830, Namur had 40 charcoal blast furnaces, and 1 coke furnace, producing 502,500 quintals; 72 fineries, 15 rolling mills,

7 foundries, and 15 puddling furnaces. In the same year, Hainaut had 4 coke and 3 charcoal furnaces at work and 8 idle, and 10 fineries. Puddling furnaces existed only at Acoz, at M. de Dorlodot's, and at Fayt at M. Dupont's. In 1830, Luxemburg, including the Grand Duchy, which had not then been wrested from us, had 21 furnaces producing 9,200 tons of iron.

In 1830, ores were still sold in the province of Hainaut at so much per "cense," which consisted of a pile of ore 4 metres square and 0·75 metres high, weighing about one ton gross, and worth from 36 to 40 francs. In the province of Namur the "cense" was only 2·65 metres square and 0·382 high, weighing about 3 tons gross, and worth from 5 to 12 francs, equivalent to 25 or 30 francs washed ore.

All statistics of the first years of the present century must be understood as representing much less than we are now in the habit of supposing. For instance, a charcoal blast furnace in 1830 produced annually 600 tons of pig, and consumed 800 "bannes" or measures of charcoal equal to 10 or 11 tons weight, and worth about 50 francs (£2) per "banne." A coke furnace at this time yielded what was then considered the enormous quantity of 2,000 tons of pig per annum, consuming ore and fuel to the extent of 262,000 francs, or £10,900. A puddling furnace, in 1830, generally made 270 tons of bar in six months' working.

Wooden and leather bellows and appliances only began to be replaced in our furnace practice, by metallic or marble pistons, in 1803, this being a British importation, as had also been the puddling of iron, as well as grooved rolls for rolling mills, and as was at a later period Mr. Neilson's great invention of the Hot Blast. From this time forward our iron manufactures went on prospering.

In 1848, we only sold iron to our near neighbours, as France, Germany, and Holland; but twenty years later, in 1868, with a truly enterprising spirit, we were sending our iron and our rails to America, Switzerland, Turkey, Egypt, Cuba, Rio, Chili, Spain, the Hanseatic Cities, Denmark, Russia, and even to our only serious competitors in the world's market, Great Britain, to which we exported that year no less than 11,630 tons of iron.

I shall limit my statistical notes to what is necessary in order to show the rapid increase of the Belgian iron trade during these latter years. In 1842, the district of Charleroi had 13 blast furnaces at work, producing 40,000 tons of pig, and five rolling mills, turning

out 21,000 tons of iron. In 1852, 17 blast furnaces in operation made 81,821 tons of pig, and the mills produced 37,326 tons of iron. In 1862, 23 blast furnaces in operation produced 199,790 tons of pig, and 32 ironworks, 112,290 tons of iron. In 1872, 30 blast furnaces in operation made 400,000 tons of pig, and the mills about 250,000 tons of iron. The total value in francs of the pig and manufactured iron, for the district of Charleroi alone, amounted last year to more than 103 millions, equivalent to about 4 millions sterling.

From the above we see, taking the yield of 1842 as a unit, that in 1852 the production was as 2·18 to 1; in 1862, as 4·99 to 1; and in 1872 as ten to 1; equivalent to successive productions of 218 per cent. in 1852, of 499 per cent. in 1862, and of 1,000 per cent. in 1872. In the same manner, the production of manufactured iron since 1842 has increased during the next decades in the ratio of 1·77 to 1, of 5·34 to 1, and of 11·90 to 1, equivalent to successive productions of 177 per cent. in 1852, of 534 per cent. in 1862, and of 1,190 per cent. in 1872.

In the province of Liége, 100 works of various kinds are in operation for the production of iron and steel, and its manufacture, sub-divided as follows:—

Manufacture of pig iron, 6 works; iron foundries, 52; rolling mills, 17; other works, 20; steel works, 3. The number of workmen in these various works amount to 10,406.

The production of pig iron, in 1871, was 178,201 tons; of castings, 26,305 tons; of rails, 35,696 tons; of merchant iron, 87,991 tons; of plates and sheets, 21,701 tons; of other ironwork, 24,092 tons; and 8,900 tons of steel. In 1872, the production was 178,377 tons of pig; 31,376 tons of castings; 103,245 tons of merchant iron; 21,271 tons of rails; 28,123 tons of sheets and plates; 19,989 tons of other ironwork; and 15,284 tons of steel. The total value of the iron and steel produce at Liége is above 85 millions of francs, or £3,400,000 sterling. We see, by this, that Liége and Charleroi together, leaving over the various works in the provinces of Luxemburg and Namur, as well as those in the district of Mons in the Hainaut, produced iron and steel to the amount of £7,400,000 sterling.

Before closing, allow me to furnish a few dates, which are interesting in many points of view.

It was in 1821 that Messrs. Huart & Henrard, of Couillet, in the province of Hainaut, erected the first puddling furnace in Belgium.

But very soon after, in 1823, M. Orban, of this city, put up the first in the province of Liége, at his works at Grivegneé.

Our iron industry was saved from complete ruin from want of ores or fuel at three distinct periods of its history. First, when charcoal became scarce and the use of coke stepped in to replace it, Messrs. Huart-Chapelle, at Marcinelle, in 1854, Lejeune, at Hourpes-sur-Sambre, Hansnet, at Couvin, and John Cockerill, at Seraing, were in this case the leaders of the movement. Secondly, when the ordinary ironstone of the country had in a great measure been worked out, when after repeated trials, the owners of the blast furnaces of Ougrée, in 1853, discovered how to utilize the vast beds of hematite scattered over the country, and which had not been used since 1790, because they produced cold short iron. The process consisted in mixing a certain proportion of the shales of the neighbouring coal measures along with the ore in the furnace. Thirdly, when these hematite ores became quite insufficient for our consumption, the minettes of the Grand Duchy of Luxemburg came into notice, and have continued to this day almost our sole resource. With collieries, most of which are worked under very great difficulties, with ores which have to be carried a hundred miles or more, with labourers who are physically incapable of doing more than half the work of an English workman, we have by dint of care, order, and especially of economy in minor details, been enabled to hold our own as iron makers among the nations of the earth, and to compete in distant markets with our only great, but friendly teacher in this line of industry—Great Britain—to whom we owe a debt of gratitude in connection with this matter. As a further proof that we Belgians follow progress, I will state that the first Danks's Rotary Puddling Furnace was put up a few months ago at the works of the Société Anonymé of Sclessin, and that the ironworks of Ougrée, and of l'Esperance, have adopted throughout their works Louth's three-high plate and sheet mills with the most satisfactory results.

As regards our steel production, I have little to say. The first attempt at making steel dates from 1753, when Louis Joseph Bridimus made some good steel, but at a price which could not bear competition with the Germans.

In 1832, other trials were made at Couvin with satisfactory results. In 1856, a company was formed at Couillet for manufac-

turing steel by the Chenot process. In 1861, Belgium produced 2,675 tons of steel, of which 100 tons only were made in Liége. In 1866, the quantity had increased to 3,820 tons. Last year, with Siemen's furnaces, at Sclessin and Bessemer Works, at Seraing, 15,284 tons of steel were made in the province of Liége alone, which was twice the amount manufactured the year before. No doubt can be entertained that this special branch of manufacture will be considerably extended over here. Already the new Bessemer works of Angleur are in full operation, and other establishments are about to be erected. All we want is to make it cheap and from ordinary ores, and for this we look forward in hopefulness to the researches of the great men of the Iron and Steel Institute, men who are an honour to the science of the present century, and whom the whole world regards as benefactors of the human race. We are proud to welcome them over here to-day.

I fear I have been too long already, and must finish by asking you to excuse my many omissions and imperfections. I should have liked to say something to you in relation to the connection existing over here between masters and men, as nowhere in the world do the workers receive the treatment they do here. Savings' banks, pension funds for the old, the infirm and widows, medical help, schools, model lodgings, and other things connected with the civilization of the labourer, or conducive to his physical and moral welfare, may be studied in this country to advantage in most of our large establishments, and especially at Couillet, at Ougrée, at Seraing, at Sclessin, at the works of the Grand Central Railroad, at Louvain, at the collieries of Mariemont, and at the Hazard Colliery, the property of the liberal and generous-hearted M.P. for Liége, M. J. D'Andrimont. Both M. Smits, director of the Société de Couillet, and M. J. D'Andrimont, have published descriptions of what they have done in this direction, and would be glad to furnish copies of their notices to any British ironmaster philanthropically inclined.

I refer those who wish for a more complete history of the Belgian iron trade to the publications of M. Stenier, of M. Warzée, and of M. Franquoi, all of whom have collected many interesting facts.

The historian will find an immense amount of curious documents, relating to our mines and ironworks, scattered in the vast manuscript collections of our national archives, where they have accumulated and remained buried for many centuries.

THE RATIONALE OF THE COMBUSTION OF GASES CONSIDERED IN RELATION TO AN INCREASED SUPPLY OF HEAT.

By M. CHARLES BOUTMY, Liége.

The utilization of the gases of blast furnaces is day by day coming more prominently to the front as one of the most important elements in the smelting of iron. Whitwell's stoves, then, seem to have attained to the very highest degree at which the heating of the air is possible in practice, require a very large supply of gas, and their effect will be more powerful in proportion to the number of stoves working to a blast furnace. But we must not lose sight of the production of the steam requisite for the blowing and other engines, and it is the gases of the furnaces also that must supply this power, only, as the serviceable effect of the gases is perhaps greater when they are used in heating the blast than when they produce steam, it is of importance to consume them as little as possible beneath the boilers, and, as a consequence, to utilize to the fullest possible extent the number of units that they are capable of producing.

I hold that the complete combustion of a gaseous mixture playing the part both of an agent of, and material for, combustion, in due proportions, can be brought about only on condition of the said mixture being raised to, and kept at, the temperature requisite for the combination of the said gases.

The process of combustion, even though commenced, is arrested by chilling the ignited mixture down to a certain degree.

The two foregoing assertions I found upon the well-known example of a piece of metallic wire gauze placed over a flame, whereby the latter is flattened, but the gases can be again lighted up above the wire gauze, provided, however, a body in a state of ignition be kept in that position. The wire gauze is a cold body that puts a stop to any combustion in progress.

Gases issuing from chimneys, when subjected to analysis, have disclosed the fact that even at a temperature of 400 degrees centi-

grade, they still retain a notable quantity of combustible gases mingled with a proportion of atmospheric air, much more than sufficient to admit of their burning if they were placed in a medium heated to the required degree.

Therefore, we are entitled to conclude:—1st. That the temperature of 400 degrees centigrade is insufficient to allow of the combination of carbonic oxide and carburetted hydrogens with the atmospheric air. 2nd. That boilers, the temperature of which hardly exceeds 155 degrees centigrade, produce upon ignited gases passing beneath them the same effect as does wire gauze upon flame, and that all their surface being in contact with the flame extinguishes a portion of it, in such wise that they are wrapped up in a sort of sheet of gaseous mixture that remains unconsumed for want of a temperature sufficiently high in degree. And the said mixture, notwithstanding that it is, owing to its composition, perfectly combustible, issues forth out of the chimney without having been enabled to serve any useful purpose.

However low we may suppose the speed of the draughts to be, we cannot estimate it at less than 3 metres per second. Consequently, this sheet extinguished from the effects of the contact with the boilers represents a most notable quantity of combustible gases that rush out of the chimney and are wasted.

To obviate this waste, it will be necessary to consume the gases in a special chamber of combustion wherein they may at all times meet with a temperature sufficiently elevated in degree to allow them to consume themselves completely, and to project beneath the boilers the products of combustion only which in passing on to the spot will carry with them the total supply of heat produced.

Although I cannot undertake to show a plan in this place for the construction of this chamber of combustion, and which would, of necessity, have to be modified to suit the requirements of each particular case, yet I may direct attention to the fact that the heat-retaining capacity of bricks is fully twice as great as their power of yielding up their caloric; and further, I may state that, according to Newton's law, where any body is exposed to a source of heat constant in its supply, its temperature does not on that account rise indefinitely, because the quantity of heat it will receive in equal spaces of time will be always the same, whereas the heat lost

by it increases in proportion to the excess of its temperature over that of the medium by which it may be surrounded.

Consequently, if we cause the gases to be burnt in a chamber filled with bricks, the latter will acquire exactly the temperature which the gases are capable of producing, and thus insure the fullest combustion of the same, while the products of combustion will issue forth out of the said chamber, bearing away with them the whole of its heat.

Under such circumstances, but a very low degree of draught speed will be required, together with large sized flues or fire tubes allowing the gases to stay the longest possible time beneath the boilers.

In point of fact, in proportion as the gases give up their heat to the boilers, they will fall down to the lower portion of the fire tubes and will be replaced by hotter gases.

Such, in my opinion, are the principles upon which must rest any arrangements having for their object the economical consumption of the gases, and thereby afford a means of utilizing the maximum supply of heat that can be produced by any given weight of gas within a unit of time.

SUMMARY OF A STATEMENT ENTITLED STUDIES RELATIVE TO THE IMPROVEMENTS WHEREOF THE CONSTRUCTION OF METAL-WAYS IS SUSCEPTIBLE.

By M. D. SOIGNIE, Engineer, Brussels.

Among the causes which are opposed to the beneficial development of the construction of railways there are two, which are the principal that are indirectly connected with the great industry of the manufacture of iron and steel—that is to say, first, the considerable expense which the working of railways cause for maintenance; second, the too heavy cost of the first establishment of the permanent way properly so called.

These studies have for their object the discovery of a means of sensibly lessening these expenses in order to permit companies to work advantageously lines established in localities but little favoured, and to thus rapidly increase the sum of the moral and physical well-being which these railways are destined to produce. Our attention has notably been drawn to the increase of the resisting quality of the iron rail; to the extension of the duration of its supports; and to the means of arriving at the passage of heavy gradients with locomotives of relatively light weight.

In order to attain these ends, we have imagined:—1st. A process of lamination calculated to improve the quality of the T rails. 2nd. A new form of rails sensibly increasing their durability, other things being equal. 3rd. A system of making rails with an entire super-raised face. 4th. A system of entire metallic way applicable to lines of large traffic, tramways, and lines in the interior of mines. 5th. A system of fastening with bolts with elastic pressure. 6th. A rail with an arched rolling crown increasing the adherence (bite) of the locomotive.

We will briefly describe these systems. Experience demonstrates that the resistance of iron rails is no longer sufficient to bear, during

a lengthened period, the enormous traffic which is at present developed upon railways; that this deterioration has become so rapid, is ascribable, in our opinion, to two causes. To the decrease in the quality of the iron used in the manufacture of the rails, on the one hand; to the great weight per locomotive axle which their construction entails, on the other hand. The decrease in the quality of the iron of the rails arises from the use in the blast furnaces of an excessive proportion of silicious ores, of slags, which affords a ringing iron, but an iron breaking without tenacity; this decrease is again induced by the tendency of the manufacturers to finish their rails at too high a temperature. The impoverishment of the strong iron ores, the vignole shape given to the rails, compel the makers to act to a certain extent in this manner. Our system of lamination has for its object the avoidance, within the limits of possibility, of this state of things. In order to correct the deficiency of tenacity in the flanges of the rails, the dominant cause which augments their deterioration, we remedy thus:—1st. By a much more energetic compression of the iron forming the T rail. 2nd. By a welding at a less temperature at the finishing rolls, without fearing the rending of the flange of the rail. In order to attain these results, the rail prepared by the ordinary method up to a certain point is completed in our special rolling mill, which is composed of three finishing rolls of a dimension of 0·70 m. at least, travelling at the rate of 1 m. per second, at the most, of which two are horizontal and the third vertical, cast in a mould intended to compress, temper, and polish highly the crown of the rail. As the finishing rolls are usually arranged, the swelling of the flange of the rail is obtained by the flattening or compressing of the iron in the finishing grooves. This effect is evidently very prejudicial to the tenacity of the iron, inasmuch as instead of compressing the molecules, they are dilated exactly at the spot where the wheels most sensibly infringe on the rails.

By our arrangement, instead of dilating the iron, we strongly compress it, absolutely as would be done by the forge-hammer acting upon the crown of the rail, and with so much the greater efficacy, as the process of the welding is slow, and the diameter of the rolls large. On the other hand, it is well known that the more granulated iron is laminated at a low temperature the closer the pores become attached, which renders it more pliant

and more hard. The contrary effect takes place when the same iron is finished hot, and that is what is effected with the mills of three rolls that are used in the present day. We avoid, moreover, this inconvenience without apparatus. The slow lamination, added to the continuous watering of the vertical compression cylinder, draws out the flange of the rail at a relatively low temperature, at the same time giving to it a sort of tempering which considerably augments the hardness and tenacity of the iron. This retardation in the definitive lamination will not, moreover, produce rending in the flange of the rails; it is known that that never takes place in the last groove.

2nd. Rail with crown super-raised.

Experience demonstrates that the deterioration of the T rail is so much the more prompt, the more decided the flattening of the head of the rail is in consequence of the wear and tear (friction). In fact, it must be so, inasmuch as the bearing of the tyres of the wheels then act upon the edges which are always the most feeble points of the rails; the tangential efforts of the wheels thus augmenting by the breadth of contact, this course of destruction becomes added to the former.

The action of the flange of the wheel tyre upon the edges of the rails is also very detrimental, particularly at the curves, because the weight thus becomes localised upon a very small surface, where the iron offers the least guarantee of resistance. The form recommended, if given to the T rail, obviates entirely these inconveniences. The form under notice retains the breadth of the upper zone of the rail, whatever may be the wear and tear, within suitable limits, and the weight can no longer act upon the edges of the rails, but only towards the centre where they have a considerable resistance, and where the quality of the iron is always superior. It is known by mechanical action of cylinders that the iron is always less sound towards the salient points than towards the centre of a section.

Experiments, carried on for the last two and a-half years, corroborate completely our provisions. They prove by evidence that the duration of these rails is more than tripled; and even rails of the description laid down since the 30th of May, 1871, upon a gradient of twenty-five millimetres, where, according to an official report, the rails of the usual form did not last three months, are

still in good condition, although very heavily used, that is to say, that up to the present time their duration is nine times greater than the rails of iron that were previously laid down upon the same place. These facts require no commentaries, and will make it comprehensible, we hope, that the interest of masters of Ironworks and Railway Companies is closely linked with the adoption of this practical form very suitable to bring up again the use of iron rails.

3rd. Method of manufacturing the rail with a super-raised crown of steel.

The super-raised crown of rails of the form whereof we have just made mention, being of steel, it can be easily comprehended that the duration of such rails will bear comparison with those of the best rails made entirely of Bessemer steel. This form permitting moreover the trimming in the portion of steel in the interior of the mass, it will be much easier to weld this portion in iron and to be thus able to obtain mixed rails at a moderate figure, capable of resisting the most destructive traffic.

4th. System of line entirely metallic.

The substitution of iron for wood, as the support of the rails, interests as well ironmasters as the workers of railways. Our system, sanctioned by experiments that have been carried on for nearly three years, has this remarkable characteristic, that similar lines can be established in ordinary times at a less price for the first laying down thereof than the Vignole line upon wooden sleepers. Enormous savings in maintenance evidently emanate from this appliance.

This metallic line laid down, and permanent, is constructed of rail supports of iron: that is to say, vignole rails carrying invariably their supports, easily transported in that state, connected together by tie pieces. If a rail becomes defective it can be raised together with its supports, and is replaced by another rail and support. The supports of the first rail can be used again. These rail supports of a new sort are upon a different principle to those upon which the English Barlow rails and the German Hartwich rails rest, without having the inconveniences of these latter. As the iron supports possess a duration almost indefinite, it is provable that after 36 years working, the kilometrique saving realisable is more than 174,000f. The same system slightly modified applied for tramways afford savings even still more considerable. For the

railways in the interior of mines it also offers great advantages, and our system of tie piece may there supersede the use of wooden sleepers. It is evident what fresh and important outlets the iron-works may find by the application of this means, the first expense no longer being an obstacle to the use of iron as the support of rails.

5th. System of splicing with bolts and elastic fastenings. The screws of the fish bolts, such as are used in the present day, under the influence of the tremulation caused by the passing of trains, soon become loosened, and consequently the splicing fails in its intent. It happens also that the violent shocks sustained by the nuts break the worms of the screws, and render the bolts unserviceable. The rusting of the threads of the screws is also a case of waste. Our system obviates these inconveniences by means of simple appendages to be placed below the flat of each screw. The appendages are composed of a washer of India rubber encircled by a ring of iron upon which the flat rests after being fastened. By this means, as experience proves, the shocks are deadened, and the threads of the screws thoroughly preserved. The junction of the rails is, therefore, much more perfect, the roll of the carriages more gentle for travellers, and the preservation of the material stationary. The Belgian Government has resolved to apply this system of splicing, which does not cost more than about 60 cents per pair of splints. This system does not entail any alteration in the form of the bolts, nor in the splinting plates. It is consequently very easy for companies working lines to apply the same.

6th. Rails with crowns striated.

It is known that the adherence (bite) of the locomotives corresponds to a fraction of the total weight divided between the coupled wheels. It is proved also that this friction increases in an inverse ratio to the surfaces in contact with the wheels. It is this latter property that we utilize to prevent the sliding of the wheels upon heavy gradients, by supposing the useful adherent weight of the engine inferior to the corresponding power of the locomotive. For this purpose, we make upon the crown of the steel rail, grooves inclined to 25 degs. upon the arch sufficiently close, in order that there be no solution of continuity in the rolling. It is perceptible that in this way the pressure of the tyres per square centimetre is nearly doubled, and that the sliding of the wheels equally weighted ought to be effected with much greater difficulty. We have not, up to

the present time, been able to determine this co-efficient, having experimented upon lines striated perpendicularly to the axis, but it is certain that the bite is considerably increased. Although the sliding of the wheels upon these rails takes place less rapidly, we do not think that the resistance to the rolling will sensibly be increased, since the frictions of the sliding, or of rolling, are quite different. If the ulterior experiments are conclusive, these striated rails which would be laid down solely upon heavy gradients, would effect a complete transformation in the construction of the locomotives, and even in the railways, because the weight and axle might be reduced. The rails and the supports would consequently suffer much less. To ascend very great gradients upon a railway with stiff curves would no longer be a problem almost unsolvable. We draw the attention of engineers to this innovation.

ON PHOSPHORIC BRONZE AND ITS PRINCIPAL INDUSTRIAL USES.

By M. C. MONTEFIORE LEVI, Val Benoit, Liége.

Although the subject of the present note might be considered as not strictly within the limits of the subjects to be submitted to the discussion of the Iron and Steel Institute, it nevertheless bears such an intimate relation to the methods of manufacture of iron and steel, that we do not hesitate to bring it under the attention of the Institute.

Our intention is not to establish any comparison between phosphoric bronze on the one hand, and iron and steel on the other, although such a comparison might present a certain interest, but if we take into consideration the importance of being able to produce by casting, that is to say, independently of any complication of shape, a metal possessing the qualities of hardness, absolute resistance, and elasticity in a higher degree than iron, and almost equal in certain cases to steel, together with the faculty of varying at will, and within very wide limits, any or all of these qualities; when, moreover, the metal may be considered as practically inoxidizable, when it shows but a slight friction against iron or steel, when it does not vary in structure by shocks or concussions, however often repeated, and preserves the entire intrinsic value of the metal when worn out or otherwise out of use, it will be admitted that the study of the qualities of such an alloy is of considerable interest to all who construct or use the numerous tools and powerful engines required for the production of iron in its many varieties.

The attention of the readers of English and foreign reviews and scientific journals has been on more than one occasion drawn to phosphoric bronze. We may specially mention the *Engineer* of the 8th July, 1870, and the 23rd February, 1872, and *Engineering* of the 9th September, 1871, and 4th October, 1872. These articles refer more particularly to the origin and to the first trials and industrial appliances of phosphoric bronze.

Prolonged experience in the manufacture has produced a more perfect knowledge of the properties and preparation of the alloy; it is thus that a far superior degree of resistance and of elasticity has been attained, whilst it has now become easy to give either of these qualities the desired predominance together with more or less hardness according to the special purpose to which the metal is to be applied.

The following table shows the result of five trials of tensile strength, made by Mr. Kirkaldy upon bars composed of one identical alloy, submitted to different processes of manufacture :—

Nos.	Ultimate Stress per Square Inch. Lbs.	Elastic Stress per Square Inch. Lbs.	Ultimate Permanent Extension. Per Cent.
1.	74·966	55·800	2·53
2.	73·987	55·200	3·20
3.	63·653	40·500	9·40
4.	54·060	26·300	31·30
5.	50·120	21·700	39·10

The Ministry of Public Works for Germany, struck by the remarkable qualities of the alloy, ordered, as a work of public utility, a series of trials to be made at the expense of the Government. As these trials, similar in nature to those made constantly during the last eight years upon the iron and steel employed in the manufacture of rolling stock and railway plant, are of considerable importance, we will in a few words describe the means used and the end attained.

The trials at Berlin have proved the correctness of the hypothesis so often broached, that iron and steel, if submitted to continually repeated efforts of tension, torsion, or flexion, give way, probably in consequence of a molecular modification of structure under an effort often considerably below that of their absolute resistance under one single strain.

These trials were undertaken by the Prussian Government with the object of establishing as a fact, that the absolute resistance and elasticity of a metal being known, such metal can only with perfect security be submitted to a limited given number of strains of a given strength in all cases inferior to the limit of its absolute resistance. M. Reuleaux, Conseiller intime, and M. Spankenberg, engineer, are conducting these trials with phosphoric bronze.

Highly interesting and elaborate details of the methods and apparatus employed by them may be found in the work of M. A. Wöhler, entitled "Ueber die Festigkeitsversuche mit Eisen und Stahl. Berlin, 1870. Ernst ū Korn."

The first series of these experiments with phosphoric bronze, as compared with ordinary bronze or gun-metal, were begun in April and ended towards the middle of May of the present year, with the following results:—A bar of phosphoric bronze was submitted successfully to 408,230 tractions, with an effort of 200 cwt. per square inch, whilst a first bar of ordinary bronze broke at an effort below 200 cwt., and a second bar resisted only 4,200 tractions. A second bar of phosphoric bronze has, at the present time, resisted 147,840 tractions with an effort of 250 cwt. per square inch, and this experiment is still in progress.

In a trial for flexion, with a maximum strain of 200 cwt. on the external fibres of the bar, these fibres alone were broken through after 862,980 flexions, whilst a similar bar of ordinary bronze, under the same strain, was broken completely through after 102,650 such flexions. A second bar of phosphoric bronze, under an effort of 180 cwt. per square inch, has, up to this date, borne 1,260,000 flexions without as yet showing any sign of deformation or of rupture.

We now come to a series of industrial appliances. A peculiar composition of phosphoric bronze, destined specially to resist friction, has been in use for several years on a large scale for bearings, particularly for rolling stock, and, among others, the Grand Central Railway Company, of Belgium, employed these bearings exclusively for all its cars and carriages. Many works, both in Belgium and Germany, employ this alloy for engine and machinery bearings. The trials made have shown that the wear by friction is about five times less than that of ordinary bearing brasses, whilst the axles remain unaltered. Several ironworks, among which we may mention Messrs. Gillieaux and Co., at Charleroi, Blondiaux and Co., at Thy-le-Chateau, Thorneycroft, at Wolverhampton, and De Wendel and Co., at Hayange, make constant use of large toothed wheels, in phosphoric bronze, for the gearing of their rolling mills in all cases where the shocks are severe. Experience has shown that in no case has a tooth of such a wheel been broken, and that the wear is less than half that of ordinary bronze. (See, for further particulars concerning this special appliance, and also on the use of phosphoric

bronze for transmission shafts for rolling mills, a note published in the "Bulletin du Museé, de l'Industrie of Belgium.

In the February number of *Engineering*, for 1873, an article was published on the use of phosphoric bronze for tuyeres, showing that such tuyeres are much superior to those in ordinary bronze, and that after a year's service they show neither fissure nor incrustations of slag or cinder. These tuyeres, already largely used in Germany, are now being tried both in England and in France.

The great resistance of phosphoric bronze has led to its use for the manufacture of cylinders both for steam fire-engines and for hydraulic presses. Messrs. Merryweather have applied it to the first of these purposes, as may be seen in all the fire-engines sent by them to the Exhibition at Vienna. Messrs. McKean and Co. have also employed it in the construction of the apparatus they have made for the boring of the St. Gothard tunnel. The great elasticity of phosphoric bronze, and its easy friction on iron, have been very successfully taken advantage of in the construction of packing rings for steam pistons.

Phosphoric bronze may be drawn out into wire, and by this process it acquires a resistance at least equal to that of any other metal capable of being drawn into wire. The following table gives the results of trials made at Mr. Kirkaldy's of such wire :—

Metals.	Pulling Stress per Square Inch. As drawn. lbs.	Annealed. lbs.	Number of Twists in Five Inches of Wire. As drawn.	Annealed.	Ultimate extension in per cent.
Phosphoric Bronze	102·750	49·351	6·7	87·0	37·5
Do.	120·957	47·787	22·3	52·0	34·1
Do.	120·950	53·381	13·0	124	42·4
Do.	139·141	54·153	17·3	53·0	44·9
Do.	159·915	58·853	13·3	66·0	46·6
Do.	151·119	64·569	15·8	60·0	42·8
Copper	63·122	37·002	86·7	96·0	34·1
Steel	120·976	74·637	22·4	79·0	10·9
Best Charcoal Iron	65·834	46·160	48·0	87·0	28·0

Besides its high absolute and elastic resistance, phosphoric bronze possesses in common with all alloys, where copper predominates, the advantage of not becoming crystalline, as is the case with steel and iron, under repeated concussions. It is, therefore, well adapted for the manufacture of mining and other ropes. The prime cost is higher than the ordinary material, but it is probable that the cost in the long run will be less, as whilst

resisting atmospheric and corrosive influences, it preserves, when worn out, its intrinsic value.

Phosphoric bronze of a suitable composition can be perfectly rolled and hammered. In Russia, several millions of cartridges have been made of this metal, and have been shown to bear firing as often as 120 times in succession, without being torn or otherwise injured.

As sheathing, it resists the action of sea water much better than copper. The following table gives the comparative result of six months action of sea water on rolled phosphoric bronze on the one hand and of yellow sheathing metal on the other, the surfaces acted upon being equal in size.

Metal.	Weight before Immersions. Kilogs.	Weight after Immersions. Kilogs.	Loss. Kilogs.	Loss. Per Cent.
Sheathing Metal ...	33·825 ...	32·805 ...	1·020 ...	3·015
Do. ...	40·413 ...	39·160 ...	1·253 ...	3·100
Phosphoric bronze ...	31·615 ...	31·260 ...	0·355 ...	1·123
Do. ...	51·970 ...	51·350 ...	0·620 ...	1·193

A similar trial, made for the purpose of ascertaining the difference of resistance to the action of an acid solution between rolled phosphoric bronze and copper, showed for three months action of sulphuric acid marking 10 degs. Baume, at the atmospheric temperature, a loss of 4·15 per cent. in the copper, and of only 2·3 per cent. in the phosphoric bronze.

Trials have been made by several Governments in regard to the use of phosphoric bronze for artillery purposes. In every one of these trials, the resistance (toughness) of the alloy has proved superior to that of ordinary gun metal, and it is only at this point of view, which alone interests its industrial appliances, that we refer to these trials in the present paper. In Belgium, at comparative trials made with bursting charges, the ordinary bronze gun burst explosively at the second round with 1,250 grms. of powder, and a projectile of 8,518 grms., while the phosphoric bronze gun resisted this charge perfectly, the normal charge being 500 grms. of powder and a shot of 3,000 grms. In France, at the comparative trials with bursting charges, the ordinary bronze gun burst explosively at the second round with 1,500 grms. of powder, and a projectile of 16,000 grms., whilst the phosphoric

bronze gun, after firing five rounds with a similar charge, burst only at the second round, with a charge of 1,750 grms. of powder and a projectile of 20,000 grms.: the cylinder had, however, got jammed into the gun. The normal charge was 550 grms. of powder and a shot of 4,000 grms. In Prussia, the comparative trials were made by firing constantly normal charges, and turning off a certain thickness of metal in the chamber after each fifty rounds. It was found that the dimensions of the phosphoric bronze guns were only altered by the firing, when the thickness of the metal had been brought down below that adopted for steel guns of the same calibre.

The Belgian Government has accepted the phosphoric bronze for the manufacture of the box of the Comblain Rifles, and for the harness buckles of the cavalry.

At the present time, besides the works at the Valbenoit, near Liége, three companies are in existence for the manufacture of phosphoric bronze, namely, Messrs. G. Höper and Co., at Iserlohn, in Germany; the Phosphoric Bronze Company, at Pittsburg, in the United States; and the Phosphoric Bronze Company, Limited, 110, Cannon Street, London, in England. The latter has exhibited ssveral of the appliances of this metal at the Kensington Exhibition

ON THE CLOSE-LAID BOILERS OF M. PAUL HAVREZ.

By M. JULES HAVREZ, Liege.

The economical raising of steam is, in a high degree, an important subject to the different industries; and at present it has acquired a more particular interest owing to the dearness of coal. I, therefore, have thought it not out of place to giye some information in this paper on the system of boilers as constructed by my brother, M. Paul Havrez, for the purpose of economizing, at the same time, fuel and the cost of first erection. It is four years since we applied, and that successfully, as far as regards the two points named, this system of boilers to each of the two collieries of the Charbonnages du Pays de Liége, near Charleroi. This system consists in placing in juxtaposition the large ordinary boiler against its two boiler tubes, and surrounding the hearth by the three generators, either close-laid or separated by fire-bricks of from 12 to 24 centimetres (5 to 10 in.) thick. (See diagram.)

By this system the largest amount of radiating heat is drawn from the hearth, which heat, according to the experiments by Peclet (Chaleur Appliquée, 1860, vol. I., page 14), amounts to one-half of all the heat generated by the combustion of the coal, and this reduces to one-half the heat to be drawn from the burning gases. Moreover, this does not affect the burning of the coal nor that of the combustible gases, by a too rapid cooling.* The plan shows, in fact, that the combustion chamber is high and roomy like the locomotive fireboxes, because the flues are 60 centimetres high and wide, so as to form a continuation of the combustion chamber, and this will not

* All experienced engineers are agreed on the danger existing in cooling the combustion of the hearth by contact of the water to be evaporated. See Tredgold steam engines, 1838, page 209; Grouvelle Guide du chauffeur, 1858—I., page 127; Davy, Ure, Stephenson, mentioned by Wye Williams, combustion of coal, 1858, page 117-121; Morin and Tresca, steam engines, I., page 243-353.

stop the flame, and will allow of the complete transformation of the coal into carbonic gas and water. Professor Ure says: "A flame in which a vessel full of water is placed becomes smoky and cold; combustion is stopped there, because the coal covers the vessel with soot. (Wye Williams, combustion of coal, 117.)" The body of gas is gradually cooled by leading it between the three boilers; on its reaching the end it is brought back, winding round the stack of the close-laid boilers; it is then made to return either above or below the hearth, to run along the other outside half, and reach the chimney placed at the back. The hot flame is, therefore, in the first place surrounded by a layer of water, which in its turn is surrounded by a layer of smoke, cooling down and preventing the stack from getting cold outside. The system of "close-laid" boilers round the hearth, therefore, does all that is required for the economical generation of steam, according to Wye Williams, first an effectual burning of the coal and gas, making them throw off all the heat they can produce, and providing for the most complete possible absorption of the radiating heat, and then of the combustible gases by their circulation sufficiently continued in contact with the water to be vaporised. The little heat lost in front of the hearth and in the chimney explains the great economy of coal which is effected.

I must now show that this system combines the advantages of inside hearths and tube boilers, or internal flue boilers, without having the same disadvantages as regards the expense of erection, as well as the complete combustion and the utilizing of the radiating and conducted heat.

They are more economical than ordinary tube or flue boilers; in fact, they require very few fire-bricks (two bands of less than 40 centimetres in height by 24 centimetres thick alongside the hearth, and two bands let in between the boilers); fewer common bricks are required than with the system of boiler tubes and flues, because the flame is led close to the boilers. They absorb much more effectually the radiating heat. As regards the economy of bricks and the utilization of radiating heat, they possess the advantages of the inside hearths.

They are more economical than the boilers with inside hearths, because the combustion takes place in a much more perfect manner, as well as because the fire is kept up much more easily. For

inside hearths the very best plates are used, thick, and difficult to make,* but in the boilers under notice such a good quality of plate is not required. Besides this, the large boiler requires to be very heavy, and, therefore, is very expensive. The cleaning and repairs are, moreover, more easily effected in connection with the M. Havrez boiler. To give a better idea of this subject, we may state that a large boiler, of 11·5 m. long and 1·40 m. in diameter, laid close to two tubes of 13·20 m. long and 0·80 in diameter (to facilitate cleaning), weighs 12,000 kilogs. for 91 square metres total heating surface, or 80 square metres after deducting the surface taken up by the several interposed bricks. One of the principal builders of the Liége Province, M. Piedbœuf, quotes at present 73 francs per 100 kilogs. for tubular boilers of 30 to 60 horse-power. The 80 square metres, corresponding to 50 horse-power, would, therefore, cost 8,700 francs. The following are the prices of boilers with two inside hearths, given at present by M. Piedbœuf, who has the speciality for the construction of these boilers:—

Heating Surface.	Horse-power.	Diameters of Boiler.	Diameters of Hearth.	Length of Boiler.	Weight in Kilogs.	Price in Francs.	Price per 100 Kilogs.
m.		m.	m.	m.			
54	30	1·80	0·68	7·	10,000	9,000	90·
63	40	2·02	0·73	8·5	13,350	11,500	86·1
80	50	2·12	0·79	9·8	15,700	13,300	85·
96	60	2·20	0·84	11·	18,800	15,600	83·

Thus the same heating surface of 80 square metres, but with one sufficiently large hearth, costs at the outside 8,700 francs, and would cost 13,300 francs with the inside hearth system, thus effecting a saving of 4,600 francs, or more than the half of the total price of the M. Havrez boiler. This comparison shows that boilers with inside hearths weigh 31 per cent. more, cost 16 per cent. more per 100 kilogs., and, finally, are 53 per cent. dearer than close-laid boilers. They provide at that extra cost only thicker heating surfaces, half-covered with ashes and less good conductors. Lastly, let it be remarked that M. Paul Havrez's system is less dangerous—first, than that of heating tubes, the plates of which rust and decay by the action of the water that remains there without evaporating;

* The hearths of tubular boilers, says M. E. Bede (Economy of fuel, page 182), are always too small, as we have stated before when speaking of boilers with inside hearths. To resist the crushing (page 170) the hearth plates are charcoal ones, 12 millimetres thick, with flanges at right angles to answer the purpose of strong ribs and to shield the lines of rivets against the action of the fire.

and, second, than that of inside hearths, because the water-level is distant from the intense heat of the hearth. After these statements, it is principally of importance to know the practical results obtained by the new system of boilers.

To that effect I made experiments on the 12th January, 1873, which began at 10 a.m. and were brought to a close at 7·45 p.m. During that time 12,540 kilogs. of water were converted into steam by means of 1,187 kilogs. of nut coals, of the size of walnuts, from the "Résolu" Colliery, producing a half-fat (kind of caking) coal. This is equal to $10\frac{56}{100}$ kilogs. of water evaporated per kilog. of coal, and to 17 kilogs. per square metre of heating surfaces. 61 kilogs. of coal per square metre of fire-grate and per hour were burnt. During these experiments, the steam pressure lowered gradually from $3\frac{1}{2}$ atmospheres to $2\frac{1}{2}$ atmospheres. The steam was measured by restoring at the end of the experiments the water-level to what it was at starting, in the boiler as well as in the tank, where the water was taken out by the feeding pump; in these conditions the eleven tons of water poured in the tank, and weighing each 1,140 kilogs., represent the quantity of water converted into steam. The coals were weighed in wheelbarrows holding 1,250 kilogs. of coal. During the experiments, 10 barrows were weighed off, altogether 12,500 kilogs., from which 24 kilogs. of stones were taken out, and an excess of coals of 39 kilogs.

The temperature of the gases has been tested by the smelting of metals, specially of tin, which melts at 230 degs.

The foregoing figures have been taken at different hours. To do this, every hour, the steam was measured for the same water level in the boiler, by the number of strokes given by the feed pump, knowing that one ton of water of 1,140 kilogs. required 163 strokes of the pump to be forced into the boiler, which corresponded to 7 kilogs. of water forced in by each stroke. The coals were weighed in charges of 10 kilogs. every hour. Portions of these coals were thrown in every four or four-and-a-half minutes, on each half of the hearth alternately in layers of 10 centimetres thickness, so that their combustion might be as perfect as possible. The draft supplied 12 to 15 cubic metres of air per kilog. of coal by an opening of a register of 18 centimetres; the velocity of the air through the opening of the ash-pit 1·45 m. was then 0·327 m. to 0·476 m.; it was often 0·38 m. per second.

The following are the results obtained at different hours:—

HOURS.	Quantity of Water turned into Steam in Kilogrammes.	Weight of Coals consumed.	Kilogrammes of Steam obtained per Kilog. of Coals.	Observations made:—1st. Of the Steam Pressure. 2nd. Of the Temperature at the Chimney. 3rd. Of the Draught.
	Kilogs.	Kilogs.	Kilogs.	
11·10 A.M. to 12·10 P.M.	1533	180	8·5	3½ atmosph. Tin melts first. Damper opening, 0·24 metres.
12·10 P.M. to 1·10 P.M.	1736	160	10·8	Tin melts no longer in the chimney.
*				
2 P.M. to 3 P.M.	1477	140	10·7	Tin melting at 2 P.M., the damper was closed to 0·18 metres, then tin no longer melted. Steam, 2½ atmosph.
3 P.M. to 4 P.M.	1372	135	10·5	Tin no longer melts. Steam continues at 2½ atmosph. pressure.
4 P.M. to 4·30 P.M.	651	70	9·3	
†				
5 P.M. to 6 P.M.	1288	130	9·9	Tin ceased to melt when the damper opening was reduced to 0·15 metre.

These results, the author considers very satisfactory.

In the presence of the great economy which we have ascertained by the daily use as well as by a number of experiments, and also the good working of our boilers, we have decided upon establishing at our Neuville Works a group of our boilers of 300 h.p. We shall therefore have at this Bank from 550 to 600 h.p. supplied by close-laid boilers. At the Résolu Bank, we have had, for the last three years, 100 h.p. obtained by this system. The proprietors of certain coalworks at Poirier, at Mont-sur-Marchienne, and at Amercoeur in the Charleroi basin, have also successfully employed the close-laid boilers of M. Paul Havrez.

The foregoing statement, laid before the Charleroi Section of the "Association des Ingenieurs Sortis de l'Ecole de Liége" has called

* The fire has then been cleaned. After this tin melted near the chimney.

† Then the fire has been cleaned. The draught improving thereby gave heat melting tin.

forth on the part of several engineers some objections which I feel bound to bring forward here. It has been contended, in the first instance, that the combustion can be made as perfect under the ordinary tubular and re-heating boilers as under close-laid boilers, and that it is enough to let the gases circulate under a sufficiently large surface to extract all the heat.

To this it may be said that in the ordinary system the radiating heat is not utilized, that it is not immediately absorbed in the boilers, that it has to remain in the flame, so that a much greater circulation of the gases is required to cool them. This explains the greater economy obtained by boilers with inner hearths, and the preference which is being given to them.

M. E. Bede writes in his Economie des Combustibles, page 196, "It seldom occurs that a tubular boiler, fairly calculated, has given less than 8 kilogs. steam per kilog. of coal, *i.e.*, 33 per cent. more than the good ordinary boilers, producing 6 kilogs. steam per kilog. of coal." I will here remark that in leading the flames through plates alone, their heat is better absorbed and without expense for bricks. Moreover, there is always loss of heat through those brick coverings. I may also state that the lower half of inner hearth tubes is of very little use as heating surface, owing to the dust and ashes which soon cover that part. Our system of close-laid boilers does away with the use of these almost useless bottom plates. Another objection has been made. It is that the radiating heat does not play an important part above the hearth, and that if each square metre of heating surface above the hearth changes 75 to 100 kilogs. of water into steam per hour, *i.e.*, 5 times more than the average of ordinary boilers, which turn into steam only from 17 to 25 kilogs., this is due not to the radiating heat, but to the great heat which the flame possesses above the hearth.

The reply to this objection is to be found in the experiments made by Péclet on the quantity of heat which radiates outside the hearth. (These experiments are related in La Chaleur Appliquée, 1860, vol. 1, pages 14 and 348). In the centre of a vertical cylindrical ring filled with water, Péclet burns coal on a grate so suspended that the radiation alone heats the envelope. He has thus found that half of the heat came out of the coal radiating in every direction, and that the other half was mixed with the

combustible gases. In burning oil, one-fourth of the flame radiated and left three-fourths in the gases of combustion. On the other hand, Dulong, Petit, and Pouillet have found by numerous experiments that an increase of temperature of 300 degs. augmented the radiation ten-fold, and that an increase of 600 degs. made it one hundred times stronger. M. Vicaire (*Comptes Rendus de l'Académié des Sciences,* 2nd Janvier, 1872, page 135), after having stated the experiments of Péclet, insists on this influence of high temperatures over the proportion of heat which is radiated. The objection has been made to the system of close-laid boilers that the tubes, more heated on the one side than on the other, must deteriorate, as had been shown in a boiler with an inner flue, the plates of which were unequally heated. I have observed that practically the plates do not deteriorate. Theoretically they should not be damaged, because the experiments by Wye Williams have shown that the plates must necessarily have the temperature of the water which cools them off incessantly. It is evident that otherwise the plates must get heated to the point of oxidation and to get burnt, which fortunately does not take place. Moreover, all ordinary boilers have the lower half in the flame and the upper half in the cold air; they are, however, nearly over their whole area of the same temperature, if not, the expansion, stronger underneath than above them, would cause them to give way, which does not occur, because there are numbers of common boilers, in use for more than twenty years, and they have not been at all injured in this respect. Even when the plate is not entirely covered by water on one of its sides, but by water mixed with steam, which conducts and absorbs little heat, Wye Williams states that if the other side of the plate is exposed to a flame of more than 1,000 degs., the heat then lodged in the plate does not reach 200 degs.

The boiler tubes, covered on one part by water more or less mixed with steam, and on the other by combustible gases of a temperature always above 200 degrees, must, therefore, possess very nearly the same heat in their different parts, and will not suffer any ill effects resulting from unequal expansion of the plates.

It has also been stated that the bricks let in between the boilers, and those separating the sundry flues, cause the loss of a considerable section of heating surface, a larger portion than in the

ordinary boiler system. In order to lessen this inconvenience, I have reduced the thickness of the fire-bricks coming into contact with the boiler and boiler tube to eight centimetres. I lose by the use of all the bricks for the separation of flues a heating surface of 7 to 11 sq. metres only of a total heating surface of 116 sq. metres in the boilers which I am now laying down. Moreover, the escapes which may exist between these bricks and the boilers, and the heat thrown off by the bricks, do not allow us to look upon the space of contact of the bricks as being a dead loss to the heating.

Lastly, I have heard objections made that the results of my experience as given above (10·56 kilogs. of steam per kilog. of coal) were the best that had ever been obtained, and that they appeared to be higher even than those indicated by theory. I will give evidence that they are perfectly in accordance with the results supplied by the latest studies,* by those of M. Scheurer Kestner principally.

This learned engineer has stated that one kilog. of coal produces 8,500 to 9,200 units according to qualities. Now, it takes about 650 units for one kilog. of water at the ordinary temperatures to change it into one kilog. of steam between four to five atmospheres of tension. One kilog. of coal will therefore turn into steam $\frac{8500}{650}$ = 13 kilog. to $\frac{9200}{650}$ = 14·1 kilogs. of water. Now, according to sundry experiments made at Mulhouse,† 3 per cent. to 7 per cent. of heat is lost for want of combustion for an air feeding of 15 to 12 cubic metres of air, and, according to Morin and Tresca, 15 per cent. to 11 per cent. of heat is lost in the chimney for a temperature of gas of 200 degs., or in all about 18 per cent. Now, 18 per cent. of 13 kilogs. is equal to 2·34 kilogs., which cannot consequently be made into steam, and reduces it to 13 kilogs. − 2·34 kilogs., = 11·66 kilogs., the quantity of water which 1 kilog. of coal developing 8,500 of units can make into steam. This quantity would reach 11·53 kilogs. per kilog. of coal developing 9,200 centig. units.

Besides this, in the 10·56 kilogs. steam, according to the experiments, water has been carried off; this quantity was, however, much less than in most boilers, because the taking up of steam occurs at

* Morin and Tresca, steam engines, V. I., pages 462 to 476, state as high results.

† *Annales de chime et de physique*, x.x., *May*, 1870.

more than 1 metre above the water-level, and because the slow combustion produces a quiet steaming.

To establish in an indisputable manner the results obtained by our boilers, I have requested that a commission of impartial engineers be formed, namely, of Messrs. Depoitier, engineer of the Corps des Mines, and Maroquin, engineering director of the Construction Shops at Couillet, whose business is connected more specially with boilers, to kindly make experiments as to the quantity of water which 1 kilog. of coal can convert into steam in the system of close-laid boilers. I have moreover appealed to all the engineers of Charleroi who were present at our Section Meeting to form this commission. I subjoin the Procés Verbal of those experiments.

Proces verbal of the experiments made by M.M. Maroquin and Depoitier on the close-laid boilers of M. Paul Havrez, established at the coalworks in the Pays de Liége, at Montigny-sur-Sambre.

Organisation of the Experiments.—Measurements of the water turned into steam.—A large barrel of about 800 litres was placed above a horizontal boiler, used as a tank, so as to let the water run into it through a large India rubber tube. The feed-pumps drew their water from this tank to force it into the boiler. The weight of the water filling the barrel completely was found to be 794 kilogs. To know exactly the weight of the water turned into steam during the experiments, the water-level in the tank was exactly ascertained at the beginning of the trial, and at the end of the experiments, the water was brought to the same level by means of the feed pump. It was so arranged that the water-level stood then higher in the large boiler than at the commencement of the experiment, and then the level was restored to its original level by evaporation. Under these conditions, the number of tons poured into the tank represented the quantity of water converted into steam. To find the exact water-level in the tank, a wood rule

was let down through the large opening or manhole used for the letting in of the water, which rule ended in a point. It was very exactly ascertained when it touched the water, by the motion which it produced on touching. A mark was then made in the rule opposite the plate of the man-hole of the tank to rest the rule against it. By inclining the rule in different directions, it was made sure that the point then touched the water. In order to bring the water-level back to its original point, it had simply to be touched by the same balancing of the rule. Thus the water-level in the tank was ascertained with extreme precision. To find the water-level in the large boiler, two floats were used in the first experiments. In order to make their indications more sensitive, a flat rule was placed on the great lever beam, longer than those beams.

The average of the oscillations of the floats was read on a vertical wood rule, on which the experimenter drew a reference line. In the first trials, the floats only worked well to indicate the ordinary water-level. When the latter was very low, the indications were slow and probably incorrect. Therefore, they could not be relied on. No other indications have been considered but those of the floats in their usual zone of oscillations. As a precautional measure, we, therefore, have used in the second experiment a registering tube, and we then discovered that the average of the oscillations of the floats gave exactly the level, because, when one operator called out that the float showed the required level of the water in the boiler, the second observed at that moment the same thing on the registering tube. By the above means the weight of the introduced water is very exactly estimated.

To have a more certain check, we have in the last series of experiments divided the latter into three parts, taking notice of the quantity of coals required to reduce to steam each time four tons or 3,176 kilogs. of water, the water-levels having been brought back to their starting point in the tank as well as in the boiler.

Measurement of the Burnt Coal.—The coal was taken from the "Résolu" pit and was of half-caking quality, and from the foot of a heap of small nuts, formed for the greater part of sparrow heads, because it was loaded in the wheel-barrows with a toothed rake to free it as much as possible from the dust. The stones were taken

out when loading. Therefore we found in our experiments only 10·6 per cent. of residue, and in the last experiment only 5 per cent. ashes. This coal was loaded on wheelbarrows, holding from 120 to 125 kilogs. The wheelbarrow was weighed empty, then loaded with 120 or 125 kilogs., and when once tared to this weight the necessary quantity of coals required to make the beam balance was added or taken off.

To secure an uninterrupted control, this supply of coal weighed in wheelbarrows was divided into quantities of 10 kilogs. by means of a box holding that weight. Thus the charges of 10 kilogs. could be regulated and the quantity of burnt coal could be hourly ascertained.

The experiment was not commenced till the boiler was in full working, *i.e.*, in its normal state. Then the grate could be cleaned without interfering with the working of the boiler. The trial was concluded by a cleaning so as to bring together the same conditions to end the experiment. The ashes were taken out and their weight deducted from the total weight of coal.

The stoker charged each time 10 kilogs. alternately on each half of the grate, say every 4 or 5 minutes each time. In this manner one-half of the grate was in full combustion whilst the other half was being charged with fresh coals. The layer of coal was not more than 10 centimetres thick. The damper was closed at each charge.

Measurement of the burnt gases.—To determine the heat in the burnt gases, we have used the temperature for the smelting of metals. The operation was conducted so as not to melt the tin, which melts at 230 degs. Thus the gases were sufficiently cooled. Strips of tin were fastened together, and were let down into the flue close to the damper, while the draft was moderated by increasing the closing of the damper to prevent the melting of the tin. The boilers were cleaned to prevent the incrustations from lessening their steam-producing power. Two neighbouring boilers were heated by a slow fire. The feed-water was not heated by the discharge of the engines—it came straight from the underground tanks.

First experiments made on the 20th April, 1872:—M.M. Jules Ziane, Dutreuz, and Laduron, invited to witness the experiments,

sent in their apologies for not being able to attend. They were therefore made by the two undersigned.

The experiments began at 10·30 a.m., but the boiler had been heated before our arrival by means of refuse or bad coal, and was not fully fired.

The water-level having lowered very much in the boiler, the floats could only act with difficulty. At the same time that we have to make reserves as to the results obtained, we, however, ascertained the water-level as well as possible. Later on, towards noon, the water having risen in the boiler, the floats acted easily, and their indications became sure. At 4 o'clock, the water-levels in the boiler as well as in the tank were brought to the points where they stood at 12·15 p.m., and these levels having been well ascertained, we were enabled to derive from them reliable results. We found an evaporation of 5,558 kilogs. of water for 530 kilogs. burnt coal, say 10·49 kilogs. of steam per kilog. of coal, and 19·75 kilogs. of steam per square metre of heating surface. During this experiment, tin melted no longer. However, the absolute pressure of the steam gradually became less in the following manner: at 2 p.m., 3½ atmosph.; at 3 p.m., 3 atmosph.; at 3·20 p.m., 3¼ atmosph.; at 4 p.m., 2½ atmosph. We wished to see the influence which the pressure exercised over the consumption of coal by forcing the fire, by opening the damper wider (which from 0·13 m. was opened to 0·25 m.) At 4·40 p.m., the pressure had risen to 3 atmospheres. However, the hearth having got clogged, and requiring to be cleaned, comparatively more coal was consumed to bring the water-level to the point where it stood at the commencement of the trial, a point at which the float acted with too great difficulty. When the water-level was brought back to that point, the pressure was lowered to 2½ atmospheres.

From 10·30 a.m. till 5·15 p.m. 9,528 kilogs. of water had been turned into steam, using 1,121 kilogs. of coal, or say more than 8·5 kilogs. of steam per 1 kilog. of coal; but the hearth had a great charge of coal at the end of the experiment, whilst at the beginning only refuse coals were used, *i.e.*, coals mixed with stones. On the other hand, this result was somewhat doubtful, because the water-level was not absolutely shown by the float at 10·30 a.m., and at 5·15 p.m.

Only the results obtained from 12·15 p.m. to 4 p.m. can be guaranteed. Their being identical with those obtained by M. Jules Havrez, in January, was most remarkable, because they show 10·49 kilogs. into steam per kilog. of coal, whilst he found 10·56 kilogs. under the same steam pressure.

As the steam pressure had lowered from $3\frac{1}{4}$ to $2\frac{1}{4}$ atmospheres, and more heat was required to make steam at $3\frac{1}{2}$ atmospheres than at $2\frac{1}{2}$, we came to the conclusion that further experiments would have to be made under a constant pressure of $3\frac{1}{2}$ and, perhaps, better, 4 atmospheres, and that the ascertaining of the water-level ought to be made by a registering tube.

On the 29th of June the two undersigned made further trials:—

We maintained the pressure at 4 atmospheres minimum, and sometimes to $4\frac{1}{10}$ atmospheres, shown by the manometer with open air (or say a tension of 51 atmospheres).

This pressure was obtained without necessitating the melting of the tin at the bottom of the chimney, nor the lifting of the damper beyond 0·15 metres.

The indications of the water-level by the float and the registering tube continued to agree perfectly. The trials were divided into three parts at the commencement, and at the end of each of which the water-level was brought to the same point in the tank and in the boiler, so that the number of tons of water poured in, during each series of experiments, represented the quantity of water turned into steam.

The experiment began at 9·20 a.m. The boiler had been heated over night with good coal, and could be considered as in a normal working order. However, the stoker, when cleaning the fire to begin the experiment, scarcely left any burning coals, so that more coal had to be used to keep up the pressure. It is thus that 175 kilogs. of coal were consumed between 9·20 a.m. to 10·20 a.m., whilst in the next hour only 125 kilogs. were used and then only 105 kilogs. Therefore, we must claim more accuracy for the results obtained between 12 and 5 o'clock in more normal conditions, and which give an average evaporation of $\frac{9{\cdot}34 \text{ kilogs.} \times 9{\cdot}72 \text{ kilogs.}}{\cdot 2} = 9{\cdot}53$ kilogs. of water per kilog. of coal.

The damper opened to 0·18 m. having caused the tin to melt, was successfully closed to 0·15 m., and again to 0·135 to stop its melting.

The following table of the experiments gives the various results obtained:—

Time.	Pressure of Steam.	Height of Damper.	Therm. of Gases.	Weight of broken up Coals.	Total.	Weight of Water	Steam per Kilog. of Coal.	Steam per 139 metre of Heating Surface.	Coal Burnt per Square Metre of Grate.	OBSERVATIONS.
A.M.	Atm.			Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	
9·20	4·0	0·18	melting							
		0·15	,,	125						
10·0	4·0	0·135	melting stopped							
10·20	4·1	0·135	,,							
10·30	4·1	0·135	,,	125	355	3176	8·95	15·88	66	
10·40	4·1	0·12	,,							
11·0	4·0	0·12	,,							
11·45	4·0	0·12	,,	115						
Noon. 12·0	4·0	0·12	,,							cleaning
Noon.	Atm.			Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	
12·0	4·0	0·14	no melting							
P.M. 12·30	$4\frac{1}{10}$	0·14	,,	135						
12·50	$4\frac{1}{10}$	0·15	,,		340	3176	9·34	16·93	68	
2·0	$4\frac{1}{10}$	0·15	melting	210						
2·30	4·0	0·15	no longer melting							
P.M.	Atm.				Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	
2·40	$4\frac{1}{10}$	0·15	no longer melting							
4·0	4·0	0·15			326·5	3176	9·72	18·1	70	
5·0	4·0	0·15								
Average found by measuring in lump					Kilogs. 1021·5	Kilogs. 9528	Kilogs. 9·29	Kilogs. 16·67	Kilogs. 66·9	Ashes 58 kilos., or 5 per ct.

(Signed) E. DEPOITIER.
,, MAROQUIN.

COMMUNICATION RELATIVE TO CONVERTING PIG IRON INTO STEEL BY BERARD'S PROCESS.

By M. Aristide Berard, Paris.

The author is the inventor of a process for the direct conversion of pig iron into steel by using gases in a reverberatory furnace with movable bottom placed in a peculiar manner. By means of an oxidising or reducing action, regulated at will by the operator, and acting in the metal bath by the help of dipping tuyeres, the decarburation of the pig iron is moderated with mathematical precision, and the waste reduced to a minimum. The puddling, in a measure mechanical, effected by the blowing in of air and gases bringing constantly together the metal and slag, facilitates the elimination of foreign bodies injurious to the quality of the steel (such as sulphur, phosphorus, &c.), allowing thereby the use of pig iron of an inferior quality in obtaining certain products. By the means adopted for the production of gases as well as for their application, the exceptionally high temperature is developed which is indispensable for the production of certain qualities of steel. The steel obtained from this high temperature, and under the action of hydrogen, without the injurious effects of an oxygenous cementation, has special qualities of resistance, malleability, and welding. Under the aforesaid conditions of manufacture, steel ingots may be obtained easily at the price of iron.

GASES OCCLUDED IN PIG IRON, STEEL, AND WROUGHT IRON.

By Mr. JNO. PARRY, Ebbw Vale.

Since the author's first communication to the Journal of the Iron and Steel Institute on this subject, many experiments have been made with a view of determining the absolute amount of gas contained in pig iron, &c., but all have been unsatisfactory on account of the impossibility of sustaining a vacuum for any length of time at fusing point of iron.

Pig iron heated in *vacuo* up to fusing point, and kept at this temperature for many days, continued to the last to evolve hydrogen and carbonic oxide in gradually diminishing quantities. It was satisfactorily ascertained that this evolution of gas was not due to leakage, for, on lowering the heat to below the fusing point of copper, a vacuum could always be obtained, and maintained for hours. It was also ascertained that carbonic oxide was evolved at a high temperature; at a low heat, hydrogen preponderated.

Specially prepared tubes, to be hereafter described, have been used for these experiments; these tubes, in addition to ordinary cleansing and drying, were heated in *vacuo* previous to use. White unglazed clay tubes, enclosed in glass tubes, were also used enclosed in crucibles filled with blast furnace slag—these tubes stood a sufficiently high heat to soften pig iron. Iron heated to full redness in these latter, evolved pure hydrogen. On increasing the temperature, hydrogen mixed with carbonic oxide came off. That this evolution of gas is due to the presence of iron in the tube, is shown by the fact that the quantity of gas varies with the weight of iron used. The following experiments show this:—

Grey Pig Iron.

Expt. 1.—12 grms. grey pig iron heated in *vacuo* 7 hours gave 52 c.c. gas—carbonic oxide and hydrogen.

Expt. 2.—4½ grms. grey pig iron heated in *vacuo* 30 hours at dull red heat gave 11 c.c. gas; ditto, again, at white heat, 9 hours, gave 23 c.c. gas.

Expt. 3.—5 grms. heated 9 hours (white heat), 34 c.c. gas.
Expt. 4.—1·12 „ „ 12 „ (full red) 6 „
Expt. 5.—5 „ in clay tube enclosed in glass tube, low heat, 12 hours, gave 17 c.c. gas, which, tested, was found to be nearly pure hydrogen.

Expt. 6.—41 grms. (in clay tube enclosed in glass tube, tube of clay moulded round both, clay tube previously ignited in *vacuo*, glass tube heated to redness previous to use) heated up to good red heat 27 hours, gave 115 c.c. gas, containing carbonic acid, 1·000; carbonic oxide, 7·70; hydrogen, 91·2. Only 5 c.c gas evolved in last 12 hours.

Expt. 7.—2·08 grms. Platina foil, heated in double Porcelain tube, heated 12 hours gave 7 c.c. gas; heated 12 hours gave 2 c.c. gas; at white heat 10 hours gave ½ c.c. gas.

Expt. 8.—5·164 grms. iron, wrapped in above 2·08 Platina, both heated in double Porcelain tube, as above, in 9 hours gave 34 c.c. carbonic oxide and hydrogen gas.

Wrought Iron.

Expt. 9.—7·96 grms. heated 30 hours (red heat) gave 4 c.c.
Expt. 10.—37 „ „ 2 „ „ „ 9·4.
Expt. 11.—16·04 „ „ 12 „ (red to white heat) gave 12·5.

Other samples were heated in *vacuo* for 7 days at varying temperatures; at a full red heat a vacuum could always be obtained, but, on raising the heat, gas again came off. The cause of this continuous evolution of gas has not yet been ascertained. It has been proved that it is not due to leakage, or to the presence of moisture, for, as regards the latter, special precautions were taken, viz., heating the tubes to redness in *vacuo* previous to use, using hot dry mercury for the pump, and the use of water for covering the joints of the apparatus was dispensed with. In addition, it was found that the India rubber corks and tubing did not evolve gas at a temperature of 70 degs. Possibly the evolution of carbonic oxide may be due to the reducing action of the carbon in pig iron on the Porcelain tube, yet wrought iron containing only trace of carbon also yields CO. It was, therefore, determined to heat the iron in *vacuo* until only traces of gas came off: next, to transfer the

iron to a Porcelain tube connected with a modification of Geissler's mercurial air pump, to be hereafter described. This apparatus was so arranged that the Porcelain tube could be exhausted of air and afterwards filled with hydrogen or carbonic oxide, the gas passing also into the calibrated glass fall tube of the pump. By means of this instrument the amount of gas absorbed on heating the iron can be noted with great accuracy, the residual gas pumped off, and, on again heating the iron in *vacuo*, the amount of gas evolved measured and compared with the amount absorbed, without removing the iron from the tube.

Expt. 1.—(Geissler's air pump used).—5 grms. wrought iron, previously heated in *vacuo* 7 days, transferred to the pump. Heated at red heat in pure H. 28 hours, absorbed 7·93 c.c. hydrogen; further heated at blow-pipe heat 6½ hours, absorbed 0·420 c.c. Total H absorbed, 8·35 c.c. Residual hydrogen pumped off, complete vacuum formed; iron heated to red heat in *vacuo* evolved 6·836 c.c. hydrogen gas; no CO_2 or CO found. Again heated 24 hours, no gas evolved.

Expt. 2.—7·96 grms. wrought iron, previously heated in *vacuo*, heated in atmosphere of CO 28 hours, 4·6 c.c. absorbed; further heated 40 hours, no absorption. Residual carbonic oxide pumped off, iron heated in *vacuo*, evolved 3·37 c.c. carbonic oxide.

Other experiments, not yet completed, with pig iron, also show that hydrogen is absorbed with greater facility than carbonic oxide, but the quantities absorbed have not yet been estimated.

5·14 grms. grey pig iron absorbed 16 c.c. hydrogen gas.
11·30 „ „ „ 20·8 „ „

Grey pig iron, heated to a white heat in an atmosphere of hydrogen, absorbed 20 times its volume; heated 24 hours in *vacuo* evolved 20 vols. hydrogen, also 2 vols. carbonic oxide. The absorption of hydrogen was most rapid at a high temperature; no absorption noted at dull red.

The gases evolved from the iron in the preceding experiments consisted essentially of carbonic oxide and hydrogen, the latter being always highest in the first portions of gas given off at a low temperature. Nitrogen was repeatedly sought for, but only found within the limits of experimental error. The following method was resorted to with a view of estimating the nitrogen supposed to be contained in pig iron:—A weighed quantity of pig iron was treated with dilute

sulphuric acid in *vacuo*, and the hydrogen evolved collected and measured.

Different weights of iron were taken from $\frac{1}{10}$ to 2 grms., and all showed a deficiency of hydrogen, *i.e.*, a less quantity of H was given off than the calculated quantity due to the composition of the pig iron.

This deficiency was sought for in the solution, on the assumption that the missing hydrogen had combined with the nitrogen of the iron to form ammonia.

Mr. E. H. Morton, F.C.S., Newport, kindly tested several of these solutions by the Nessler test, and found ammonia in all, but in such small quantity as to be, in his opinion, within the limits of error of experiment, stating that even during the short time the solutions were exposed to the atmosphere sufficient ammonia might be absorbed to account for the quantities found. A fresh series of experiments is, however, in hand, and, with the experience gained, it is hoped that by the above method the question of the existence of nitrogen in iron will be settled. All yet made point to the non-existence of nitrogen in pig iron.

PROF. TUNNER ON THE VALUE OF SUPER-HEATED BLAST IN THE WORKING OF BLAST FURNACES.

TRANSLATED FROM THE GERMAN BY MR. H. ROCHOLL.

MOST metallurgists remember that on the first introduction of hot blast in the working of blast furnaces, the temperature of the same, taken at the tuyeres, amounted from only 150 degs. to 300 degs. C. (302 degs. to 572 degs. F.) Nevertheless, a saving of 15 to 30 per cent. and more of fuel was everywhere experienced, and the only objection against the use of heated blast was the circumstance that, in some instances, the saving of fuel was accompanied by a deterioration of the quality of the pig iron. Chemical analysis has proved a larger amount of silicon to be the cause of this pig iron being objected to. In all probability, this higher percentage of silicon results from the circumstance that heated blast produces a higher temperature, particularly of the lower part of the furnace, where the reduction of silicon takes place. The first and most natural means to diminish the temperature of the lower parts of the furnace, and to obtain conditions similar to those when using cold blast, was found in the increase of burden; but it appeared that this did not effect in all cases what was desired; in several instances a perfect reduction and the desired degree of carburization were not obtained. The limits of those conditions under which the pig iron is grey or white seem to approach each other so closely that, for a long time, particularly in Inner-Austria, metallurgists doubted whether heated blast could be advantageously used for a regular production of white iron. After a closer study of the blast furnace process, however,

another remedy against an excessive formation of silicon was found, which did not impair the reduction and carburization of the metal; a more basic slag, obtained by an additional quantity of limestone, appeared to have a firmer hold of the silicon, and to prevent its entering largely into the pig iron. This expedient is employed successfully in all those cases in which the ore does not already contain an excess of lime, for, by the presence of a large excess of lime, sulphur enters into combination with this earthy base. In some few cases, a widening of the crucible, or lowering the pressure of the blast, is found useful; these expedients, however, are applicable only within narrow limits prescribed by other conditions. In all those cases where an increased proportion of silicon is not objectionable but rather desired, the above-named means of reducing its amount are of course not used, and the introduction of heated blast under such conditions was, from the beginning, followed by the greatest success.

At the present time, hot blast, in consequence of the saving of fuel it effects, is of so universal application, that only exceptionally a blast furnace worked with cold blast is met with; but another question recently has arisen and is discussed eagerly among scientific and practical metallurgists, viz., the highest temperature at which an increased heating of the blast would be accompanied by increased economy.

In England, ever since Neilson in 1827 introduced hot blast, a higher temperature has been worked with than in any other country. From England, particularly from the Cleveland district, recently has originated a considerable enlargement in cast iron hot blast stoves, as well as the introduction of Cowper's and Whitwell's stoves, by means of which iron smelters have been enabled to convey a blast of 500 degs. to 800 degs. C. (932 degs. to 1,472 degs. F.) into the furnace. In the same district, particular attention has been paid to a scientific investigation of the blast furnace process, most prominently by Mr. I. Lowthian Bell. In England, consequently, this question has originated, and there, most probably, will it first be decisively solved. This circumstance, however, does not exclude this matter from being again discussed in this place.

The majority of English metallurgists and iron smelters, according to the papers and discussions reported in the *Journal* of the Institution of Civil Engineers, pronounce the highest possible temperature

of blast to be most economical, or at least they are of opinion that the limit beyond which increase of temperature does not increase economy has not yet been reached, still less exceeded. The other party, which believes that this limit has already been passed, at least in the Cleveland district, is headed by Mr. I. L. Bell, and for this reason their views call for closer criticism, as Mr. Bell recently has directed more attention and labour on the study of the blast furnace process than any other metallurgist.

A final settlement of this question is made more difficult by the circumstance that the consumption of fuel is influenced not only by the temperature to which the blast has been heated, *i.e.*, by the quantity of heat which it conveys into the furnace, but also by the dimensions of the furnace, which determine the degree to which the heat, conveyed into and generated in the furnace, is utilised. Not only the temperature of the blast, but, at the same time, the capacity of the furnaces has, of late years, been largely increased; consequently, it is difficult to make out for certain how much of the saving in fuel is due to the higher temperature of the air, and how much to the increased capacity of the furnace. If, besides, the material (ore and fuel) operated upon, or the quality of the pig iron, has changed, it will be still more difficult to assign to the increased temperature of blast its due share of the saving of fuel.

I shall begin by giving a short account of the opinions, investigations, and experiences, the publication of which has caused Mr. I. L. Bell to be acknowledged as one of the leading metallurgists of the present day.

Mr. Bell, in order to make out his case, assumes a blast furnace so large that the charge on going down may absorb the sensible heat of the gases, as well as saturate them with oxygen from the ore, as completely as is compatible with the nature of the blast furnace process. When in such a furnace the cold blast is changed for hot, say of 485 degs. C. (905 degs. F.), it seems clear that, as far as intensity is concerned, the same should take place in a larger as in a smaller furnace, and the same extraordinary consequences should be looked for if really they were depending on the increased intensity. This, however, is not the case, for if the furnace is so large that it affords the time required for finishing in proper time the two processes of reduction and smelting, a unit of heat, entering it by way of the blast, cannot be more effective than a unit generated

in the furnace itself by combustion of fuel.* According to Mr. Bell's view, it is therefore much simpler, and consequently more economical, to burn the whole of the fuel in the furnace itself with cold blast, instead of burning part of it in a stove, and heat the blast. In that case only, according to this theory, an advantage is to be gained by heating the blast, if it is done by a less valuable fuel which cannot be utilised in the furnace itself, *e.g.*, the furnace gases, or by impure and less expensive small coal, &c.† This practically is the case, particularly as the furnace gases are universally used for the purpose; the question remains to be answered up to what extent the combustion of the expensive furnace fuel may economically be replaced by heat of the blast.

The chemical laws according to which the power of CO of reducing oxides of iron diminishes in presence of CO_2, which acts as an oxidising agent, establish a limit beyond which an increased temperature of blast is useless; with the increase of heat necessarily the proportion of CO increases, which is supplied by the combustion of fuel. Mr. Bell has shown by experiments that at 300 degs. C (572 degs. F.) a mixture of 100 vol. CO and 50 vol. CO_2 is indifferent to oxide of iron, as it occurs in calcined Cleveland ore, while the same quantity of CO mixed with 45 vol. CO_2 effects a partial reduction of the oxide of iron. This latter mixture, however, at 600 degs. C (1,112 degs. F.), has no longer reducing but oxidising properties.

Mr. Bell, in consideration that the chemical action of this mixture is only slow, and the temperature increases downwards, assumes that a saturation of the gases with oxygen, to a degree corresponding to a mixture of 45 vol. CO_2 and 100 CO, does practically not take place, and he fixes for calcined Cleveland ore a proportion of 40 vol. CO_2 to 100 vol. CO as that at which no more oxygen is taken up. Mr. Bell calculates that for an ore which yields 40 per cent.

* Nothing can be said against this; on the contrary, the general abandoning of Cabriol's hot blast stove confirms this view. Quite different, however, are the conditions when the blast introduces only the heat, not the products of combustion from the stove into the furnace.

† The advantage to be gained by the more perfect combustion obtainable in stoves compared with the combustion in the blast furnace (which yields more CO_2) cannot be of much consequence, it being counter-balanced by the considerable amount of heat escaping in the waste gases of the stoves and lost by radiation between the stove and the tuyeres. More important is the convenience which changing the temperature of the blast affords for quickly regulating the working of the furnace.

and requires 15 cwt. of limestone per ton of pig iron, 93,000 calories are required per ton of pig iron.*

To generate these 93,000 calories by cold blast, at a proportion of 40 vols. CO_2 to 100 CO in the escaping gases, 25½ cwts. of good Durham coke are required. Now, as this proportion of CO and CO_2, calculated from the amount of oxygen to be removed from the ore, requires only so much carbon as is contained in 21 to 21½ cwts. of coke, it follows that 4 out of these 25½ cwts. may be saved if the heat (represented by those 4 cwts. of coke) is conveyed into the furnace by way of the blast. This is accomplished by heating the latter to about 485 degs. C. (905 degs. F.) What, however, will be the result when the blast is introduced into the furnace at about 800 degs. C. (1,472 degs. F.)? Evidently this additional heat will increase the temperature of the whole contents of the furnace, and on reaching the zone of reduction, will enable the CO_2, which was inert at the lower temperature, to take up carbon in the now increased temperature.

This gasification of carbon in the zone of reduction, and consequent diminution of the quantity arriving in the zone of combustion, will again lower the temperature of these two zones, and, finally, as

* No. 1.—In the zone of fusion :—		
Fusion of pig iron	6,600	
Do. of slag	17,000	
Decomposition of H_2O in blast	2,800	
Reduction of P_2O_5, SiO_2 and SO_3	4,000	
Expansion of blast	4,050	
Radiation from walls	450	
		34,900
No. 2.—In the zone of heat absorption, transmitted through the walls of the furnace ...		2,500
No. 3.—In the zone of the decomposition of limestone :—		
Expulsion of CO_2	5,550	
Decomposition of do.	5,760	
		11,310
No. 4.—In the zone of reduction :—		
Reduction of Fe_2O_3	33,100	
Carbon impregnation	1,440	
Evaporation of water in coke...	300	
Radiation from walls	650	
		35,490
No. 5.—Carried off in gases		8,800
		93,000

the excess of heat conveyed into the furnace increases, the proportion of CO_2 in the furnace gases will decrease. Mr. Bell always has found proof of these reactions in his investigations on the subject, and he shows, from the results of a furnace at the Barrow Iron Works, and some furnaces of the Middlesbrough district, that the highly-heated blast from Whitwell stoves, compared with blast heated to only 450 degs. or 500 degs. C. (842 degs. to 932 degs. F.), did not effect any further economy of fuel.

Mr. Bell admits brick (Whitwell) stoves to possess considerable advantages over cast iron ones, but for sufficiently large furnaces he does not put any value on their power of giving constantly a temperature of 500 degs. C. (932 degs. F.), simply because such a high temperature is useless. If, however, the particular nature of certain ores or fuel necessitates the use of small furnaces, the more highly-heated blast proves a valuable help. The power of the blast furnace gases of taking up oxygen reaches, according to Mr. Bell, its limit when 30 per cent. of the CO are transformed into CO_2. Consequently, when this proportion is reached, further economy ceases, as they have no further reducing power.

From Mr. Bell's lengthened experience, it appears that a furnace 80 feet high, and of a capacity of 12,000 to 16,000 cubic feet, has all the advantages which can be gained by increasing its size; furnaces of a capacity up to 41,000 cubic feet, which lately have been erected in the North of England, have not realised corresponding advantages. According to Mr. Bell, in a furnace of 16,000 cubic feet, the limit is reached to which the waste gases may be cooled and saturated with oxygen; nor does the production of pig iron keep pace with the increasing size of the furnaces, as is evident from the following data:—

Cubic capacity of furnace, in cubic feet	6,000 ...	12,000 ...	16,000 ...	26,000 ...	41,000
Weekly production, in tons ...	220 ...	260 ...	350 ...	400 ...	550
Weekly production per 1,000 cubic feet, in tons... ...	37 ...	23 ...	22 ...	16 ...	13

I mention one more statement which Mr. Bell has experimentally proved. As the quantity of heat carried away by the waste gases is represented, even with the largest furnaces, by 2 to 3 cwts. of coke per ton of pig iron, Mr. Bell, in order to gain a better insight into the circumstances affecting the temperature of the upper part of the furnace—termed by him the zone of reduction—has made

the following experiment: He replaced in a regularly working furnace the burden of calcined ironstone by an equal weight of slag and flints, a mixture perfectly neutral to CO, and continued this mode of charging for many hours. The result was an immediate fall in the temperature of the gases, and subsequent rise as soon as calcined ironstone was again charged. This experiment seems to prove that, in contradiction to the usually adopted assumption, a development of heat takes place in the reduction of oxide of iron.

As the work of the blast furnace consists not only in the smelting of the charge, but, at the same time, or rather previously, in the reduction of the oxide of iron and immediate carburization of the iron produced, it is clear that for the performance of these processes a certain weight of fuel is necessary. Now, if it be universally correct that the power of the blast furnace gases of taking up oxygen, without simultaneously re-oxidising reduced iron, ceased as soon as they contained 40 vols. of CO_2 on 100 of CO; furthermore, if in the large furnaces the reduction of the ore really be completed at a temperature of 400 degs. to 500 degs. C. (752 degs. to 932 degs. F.), nothing could be said, in my opinion, against Mr. I. L. Bell's theory and calculations, at least as far as it concerns the production of white iron. But a much larger proportion of CO_2 exists in the gases from our furnaces which smelt easily reducible ores by means of charcoal, as is shown in Messrs. R. Richter and R. Schœffell's analyses published in this journal (Berg- und Huettenmaennisches Jahrbuch) and the reduction is completed at a much higher temperature, below the boshes, as well in our furnaces, according to Prof. Kupelwieser and Schœffell's and my own observations, as in the Swedish charcoal furnaces, as shown by M. Rinman. This latter statement that the reduction is completed at a higher temperature of 800 degs. to 1,000 degs. C. (1,472 degs. to 1,832 degs. F.) is corroborated by Dr. C. W. Siemens, at least for the denser kinds of iron ore, *e.g.*, magnetic ore. Mr. Bell himself, in his several publications on this subject, has repeatedly stated that his calculations in the first instance refer only to Cleveland iron ore. Under these circumstances the discussion of the economical value of superheated blast does not seem a superfluous one, notwithstanding Mr. Bell's most valuable work on the subject.

I first will try to show by calculation that the proportion of CO_2 to CO in the waste gases of our furnaces must be considerably

higher than 40 vol. of the former to 100 of the latter, corroborating Messrs. Richter and Schœffel's analyses, the correctness of which from some sides has been doubted.

Adopting Mr. Bell's mode of computation, I calculate the quantity of heat absolutely necessary for the production of 1 ton of white pig iron in the Inner-Austrian charcoal furnaces as follows :—

	Units.
1. Evaporation of water in charcoal	400
2. Reduction of ore and carbon impregnation ...	32,400
3. Decomposition of moisture in blast	1,600
4. Heating and fusion of pig iron (Rinman) ...	6,800
5. Do. of 14 cwts. of slag (Rinman) ...	6,160
6. Reduction of silicon and other impurities ...	1,000
7. Transmission of heat through walls of furnace and heating of tuyere water (Bell) ...	3,840
8. Heat in waste gases, escaping at a tempera- of 300 degs. C. (572 degs. F.)	6,600
	58,800*

This quantity of heat is generated, the furnace working regularly and with a blast of 300 degs. C. (572 degs. F.), by a charge of 14 cwts. of charcoal, containing about 12·6 cwts. of pure carbon. After deducting ·9 cwts., as the quantity taken up per ton of pig iron, there remains available for combustion 11·7 cwts of carbon.

	Units.
This quantity on burning to CO yields $11{\cdot}7 \times 2480 =$	29,016
60 cwts. of blast of 300 degs. C. yields $\cdot 237 \times 60 \times 300 =$	4,266
Total	33,282
The required quantity was	58,800
Leaving to be supplied by combustion of CO to CO_2	25,518

In order to generate this heat $\frac{25518}{2400} = 10{\cdot}64$ cwts. of CO have to be burnt to CO_2. Now the above 11·7 cwts. produce 27·30 CO,

* This figure is more likely too low than too high, the absorption of heat by expansion of the blast not being taken into account. The quantity of this certainly amounts to more than the heat, which, as Mr. Bell has proved, is generated in the reduction of the ore, and which has been neglected in this calculation.

so that after deducting 10·64 there remain unchanged 16·66 cwts. CO. Consequently, in order to generate 58,800 units, 16·66 CO and $10{\cdot}64 \times \frac{22}{14} = 16{\cdot}72$ CO_2 (or by volume 64 CO_2 on 100 CO) have to be formed. Herr Schœffel found, in 1871,* 58·3 CO_2 on 100 CO ; Herr Richter's analysis of 1859 shows even more CO_2 than CO. We certainly may conclude that the proportion of 40 CO_2 to 100 CO, on which Mr. Bell's calculations are based, cannot be universally accepted as true.

If, as Mr. Bell assumes, the reduction of oxide of iron be effected only by CO, and the whole of the iron brought into the furnace in the state of $Fe_2\,O_3$, the reduction of 19 cwts. of iron would require 14·2 cwts. of CO and produce 22·2 CO_2, while, according to the above calculation, the generation of the necessary heat requires only the formation of 16·72 CO_2. If, in the process of reduction, 22·2 cwts. of CO_2 were formed, the weight of CO remaining, at a consumption of 14 cwts. of charcoal, would be only 13·1 cwts., consequently 108 vols. CO_2 on 100 CO would result, a proportion which, by the late Prof. Richter, has actually been shown to exist in the gases from the Wrbna furnace at Eisenerz.

However doubtful it may seem, after more recent investigations, whether such a large proportion of CO_2 ever does occur in furnace gases, certainly there can be no doubt that in the working of our blast furnaces for white iron, under the conditions on which the above calculations are based, the reduction of the ore demands the formation of a larger quantity of CO_2 than the generation of the heat required for the smelting necessitates, and consequently that, in accordance with Mr. Bell's theory, a higher temperature of the blast cannot be accompanied by a greater saving of fuel. It seems a vain endeavour exactly to fix the highest temperature at which, in our production of white iron, the heating of the blast is accompanied by a corresponding saving of fuel; the doubt which still exists about the conditions under which the reduction of the oxides of iron takes place, does not allow the assumption of incontestible bases for calculation ; however, so much seems almost certain, that at a temperature of 300 deg. C. (572 deg. F.), the limit is not only reached, but most probably passed. Thus the erection of the more expensive hot blast stoves (large cast iron ones, or Whitwell's), for our blast furnaces in the production of white iron

* Berg und Huettenmaennisches Jahrbuch of 1873, p. 188.

is only so far of advantage as the temperature of the blast, which can be regulated at will, and raised very high, affords a convenient means of regulating the working of the furnace.* Very different, however, are the conditions under which grey iron is produced in Inner-Austrian blast furnaces, respecting which, since the introduction of the manufacture of the deep grey Bessemer iron, several valuable observations have been made.

In Neuberg formerly, at a temperature of blast of 200 degs. C. (392 degs. F.) and a yield of 44 to 45 per cent. of pig iron, 15·4 to 15·6 cwts. of charcoal were used per ton of white iron, and 23 to 24 cwts. per ton of grey iron, *i.e.*, 50 per cent. more fuel was consumed for the production of grey Bessemer iron than was used for white. Lately, by heating the blast to about 500 degs. C. for the production of Bessemer iron, the consumption has been reduced to 19 to 20 cwts., a saving of more than 25 per cent. against the weight required at a lower temperature. In the Carinthian blast furnaces at Loelling, Treibach, and Heft, many years since, only 12·6 to 14 cwts. of charcoal were used per ton of white pig iron, at a temperature of blast of 160 degs. to 200 degs. C. (320 degs. to 392 degs. F.) and a yield of 50 to 54 per cent. At Treibach, a further economy of fuel on using hotter blast has been asserted, but afterwards doubted; only so much is certain that the quality of the white iron produced at a temperature of blast of 500 degs. C. (932 degs. F.) has been by all consumers objected to, and its production has been accompanied by many irregularities. For the production of grey Bessemer iron of first-rate quality, however, at Heft, the consumption of charcoal has been reduced from 20 cwts. and more at 200 degs. C. (392 degs. F.) to 17 to 18 cwts. at 350 degs. to 400 degs. C. (662 degs. to 752 degs. F.)

It seems certain that at Treibach, when with the use of highly heated blast the burden was considerably augmented, in order to avoid the formation of grey iron, a perfect reduction did not take place, in consequence of which, what is called a boiling slag (Kochschlacke) formed in the crucible of the furnace. In conse-

* I must confess that formerly I have put too much trust in several communications which I received as to the saving of fuel, consequent on the use of highly heated blast in the production of white iron. The charge of charcoal being universally measured by volume, I have lately had made exact determinations of the weights of many charges by some of my younger fellow-workers, and so found inaccuracies in several of my former figures.

quence of the boiling the pig iron grew porous, intermixed with slag, though still of a greyish character, owing to the high temperature at the tuyeres. At Heft and Neuberg, however, in the production of grey iron with a consumption of 17 to 20 cwts. of charcoal, even at a high temperature of the blast, the quantity of CO required for complete reduction is present in sufficient quantity.*

This difference in the value of superheated blast for the production of white and grey iron, not at all entered into by Mr. Bell, is of particular importance for our easily fusible, mostly manganiferous ores; for in smelting these ores the difference in the consumption of fuel for the one or the other quality is considerable, and even in the most favourable case the quantity of charcoal required is so large that a deficiency of carbonic oxide is not to be feared.

I believe, in consideration of these facts concerning our charcoal furnaces, that in the smelting of easily reducible ores with charcoal the proportion of CO_2 to CO may reach 60 vols. CO_2 to 100 CO. If in the production of white iron at a temperature of blast of 200 degs. to 300 degs. C. (392 degs. to 572 degs. F.) the quantity of CO_2 in the waste gases does not come up to these proportions, then greater economy may be expected from a higher temperature of blast, without impairing the quality of the pig iron. A deterioration of the same will in any case be owing rather to a cold working of the furnace than to an increased reduction of silicon, which latter is easily prevented by the means enumerated above.

The considerable advantage of highly heated blast for the production of Bessemer iron above referred to, and proved by the results obtained at Neuberg and Heft, is owing, I believe, not only to the higher consumption of carbon generating an excess of carbonic oxide, which is required for this quality of iron, but no less to the circumstance that in using highly heated blast, the temperature of the upper part of the furnace is relatively lower, and of the lower parts higher than is the case with cold or moderately heated blast.

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* I would not by any means dissuade smelters from constructing larger hot blast (cast iron or brick) stoves for our furnaces, which at present are worked for white iron. Such stoves, besides being periodically useful for regulating the working of the furnace, are certainly of greater durability; besides, the demand for Bessemer iron increases annually, and undoubtedly in a short time our iron ores, being so exceedingly poor in phosphorus, will be universally smelted for Bessemer iron, so that the production of white iron, now almost universally practised, will be the exception.

Though I must own that I have not succeeded in proving the increased intensity of highly heated blast in experiments which I performed in the laboratory of the Mining Academy at Leoben, with the assistance of Profs. Kupelwieser and Schœffel, so much, however, is certain, that on using heated blast (unmixed with the gases of combustion from the stove), a higher temperature must exist in the lower part of the furnace than with cold blast, because, in the first case, the same quantity of gas, and equally the temperature of the upper part of the furnace, must be lower, because, with the smaller quantity of gas and increased burden, the absorption of heat must be quicker and more complete. This is proved by the frequently observed fact that in using hot blast, the lower parts of the furnace are more rapidly eaten away than with cold blast. This distribution of the heat is a necessary condition for the production of grey iron, which, when cold blast is used, can only be gained by a greatly increased consumption of fuel.

REPORT

ON THE

PROGRESS OF THE IRON AND STEEL INDUSTRIES

IN FOREIGN COUNTRIES.

By DAVID FORBES, F.R.S., &c.,

Foreign Secretary to the Institute.

II.—1873.

A. METALLURGICAL TOPOGRAPHY.

Africa.—In consequence of the continuance of the civil war in Spain, and the interruption thereby caused in the mining operations and exportation of iron ores from the district of Bilbao, still more attention than hitherto is now directed to the exploration of the deposits of rich iron ore which are met with so abundantly on the Mediterranean coast of Africa, and large quantities of these ores are now exported not only to France as before, but also to this country, Belgium, Germany, and even to the United States. In the first ten months of 1873, France imported 232,805 tons of iron ore from Algeria, and we understand that the Creusot Company have recently acquired the Beni-Susuf and Gar-el-Baroud iron mines, situated near the embouchure of the river Tafna, in the province of Algiers.

From New York, it is announced that about 20,000 tons of iron ore have, during the course of the last summer, been imported direct from Bona, in Algeria, one-half for the Bethlehem works, and the remainder for the Trenton Steel Works. It cost about 48s. when

delivered in New York, and was guaranteed to assay sixty per cent. metallic iron along with about six per cent. of manganese; this ore was intended to be used for the production of Bessemer pig iron.

The total production of iron ore in Algeria, in 1872, is given at 334,924 tons, and the total quantity exported to all countries during the interval from 1867 to 1870, at about 800,000 tons; from one mine alone, 55,000 tons of ore was exported to England in the first eleven months of 1872.

M. de Marigny, late director of the Geological College of Algeria, has recently reported upon some large deposits of iron ore which crop out on the right bank of a small river called the Oued-el-Keddache, and are situated at an elevation of about 830 feet above the sea level; about two miles from the port "Aux Poules," and on the line of the projected railway from Algiers to Bongie and Delhys, which passes through the concession of some 2,000 acres in area, held from the government direct upon the usual royalty on all ore extracted. The lode is seen to follow the right bank of the river for some sixty yards, where it is from 36 to 60 feet in width; judging from the numerous large detached blocks of ore strewed on the surface for a great distance it would appear probable that this deposit is a very large one. The ore was found to contain 65·9 per cent. metallic iron, and to be free from both sulphur and phosphorus; its complete analysis showed its percentage composition to be as follows:—

Sesquioxide of iron	95·00
Alumina	1·50
Carbonate of lime	1·50
„ magnesia	1·00
Silica	0·70
	99·70

It is understood that Messrs. Bolckow, Vaughan, & Co. have, owing to the deficient supplies from the north of Spain, made arrangements for obtaining large quantities of iron ore from mines in Tunis.

A paragraph has been going the round of the newspapers to the effect that there have recently been discovered, close to the Hills of Moses, near the Red Sea, the remains of immense ironworks, supposed to be at least three thousand years old, and which must have given employment to thousands of workmen.—Near the remains are still to be seen the ruins of a temple, and of barracks for the soldiers who have been employed in protecting or keeping the workmen in order.

AUSTRALIA.—Valuable deposits of iron ore, with seams of coal and fire-clay, are reported as having been discovered in the Strzelecki Range, Gipps' Land, in the property of the Great Victorian Gold Mining Company. At Ballarat, eight veins of ironstone, which contain from 50 to 60 per cent. of metallic iron, and are said to be from 30 to 40 feet in thickness, have been met with on the western slope of the Moorabool river, in Victoria; deposits of fire-clay and lignite occur in the neighbourhood, and the country is covered with timber, which could be used for making charcoal.

AUSTRIA.—The great event of the year in this country was naturally the international exhibition, of which, however, so many and so detailed descriptions have already been given in other periodicals, that it is not considered necessary in the present report to make more than a passing reference, and to remark that such exhibits in connection with the iron and steel industries, as were particularly noticed, will be described under the heads of the various countries from which they proceeded. Although, as regards iron and steel, the Austrian and Hungarian works were well represented, there did not appear to be anything specially interesting for its novelty amongst the exhibits. From the Suedbahn Eisengesellschaft's Works, at Graz, in Styria, excellent steel rails manufactured by both the Siemens-Martin and the Bessemer processes were exhibited, as well as iron rails puddled in the Danks' rotary furnace; amongst other exhibits were, iron and steel from Kamatow; iron castings from Archduke Albrecht's works, at Teschen; steel and castings from Janowitz, in Moravia; and irons from Siebenburgen and Hungary; good specimens of cast iron railway wheels were sent from Count Andrassy's, Dornac Iron Works, in Upper Hungary, and also by Messrs. Ganz & Co., in Pesth; and from the Reichenauer Iron Company's mines and furnaces at Edlach and Reichenau, near the Semmering, on the Styrian frontier, fine cast iron shells

were exhibited, one of which, nine inches in diameter, had perforated an eleven inch armour plate without other signs of injury than some three or four minute cracks at the commencement of the ogival part.

Specimens of iron dephosphorized by Jacobi's process, which some time back was described in these reports, were exhibited by the Kladno Iron Works.

As regards the literature of the Vienna Exhibition in so far as relates to the iron and steel industries, the following publications may be found useful for reference:—

Kurzer Bericht ueber die bei der Wiener Weltausstellung, 1873, zur Anschauung gebrachten Eisenhuetten-Producte, Eisen-und Stahl-Arbeiten, von huettenmaennischen und gewerblichen Standpunkte aus und besonders unter Beruecksichtigung der Deutschen Zustaende, von Ed. Schott, Oberhuetten-inspector in Ilsenburg am Harz, Juror in der 7 Gruppe und Delegirte zur 1 Gruppe. Leipzig, 1873, Felix, pp. 34, 10 ngr. (A short report on the products of ironworks, and works in iron and steel exhibited, considered from a metallurgical and industrial point of view, and with special reference to German circumstances. By Edward Schott.)

Das Eisen auf der Wiener Weltausstellung, 1873; Bericht an das Koenigl, Ungar, Finanz-Ministerium von Auton Kerpely, Ber: rath, ordentl. Professor fuer Eisenhuettenkunde und Eisenhuetten-Anlagen an der Koenigl-ungar-Berg-und Forst Akademie in Schemnitz, 1873. Schemnitz Verlag von Aug Goerges. 3 th. (Iron in the Vienna Exhibiton, a report to the Hungarian Minister of Finance, by Professor Kerpely.)

Denkbuch des Oesterreichischen Berg und Huettenwesen. Aus Anlass der Wiener Weltausstellung, herausgeben von K.K. Ackerbau-Ministerium unter Redaction des Ministerialrathes Anton Schauenstein, 1873. Wien verlag des K.K. Acherbaw-Ministerium. (Memorandum book of the Austrian mining and smelting industry, in connection with the Vienna Exhibition, which contains a great deal of information on the iron mines and works of the Austrian Empire.)

A series of papers on the iron manufacture at the Vienna Exhibition will be found published in the Numbers of *Engineering*, during the months from July to October.

Very excellent cast iron ordnance, which are cast solid and allowed to cool very slowly, are made in Austria, at the Mariazelle Iron Works, in Styria, where calcined spathic iron ores, containing about 42 per cent. metallic iron, are smelted, using cold blast, with an average consumption of about 12 cubic feet of fir charcoal to the 100 lbs. of iron, and a flux ferruginous limestone, along with a little clay slate containing carbonate of iron disseminated through

it. Analyses of the ore, limestone, and clay slate, made in Vienna in 1869, gave the following results:—

	Calcined Spathic Ore. GALLRAD.	Limestone. ROTHSTHAL.	Clay Slate. —
Protoxide of Iron ...	65·64	20·66	7·22
" " ...	1·79	—	—
" of Manganese	3·22	2·16	1·16
Oxide of Copper ...	0·02	—	—
Lime	1·30	34·05	2·90
Magnesia	9·43	2·55	0·83
Alumina	2·36	3·89	15·66
Silica	13·40	5·30	66·60
Carbonic Acid	2·50	31·00	5·63
Sulphuric "	0·29	0·10	—
Phosphoric "	0·12	0·11	—
	100·03	99·82	100·00

Whilst the cast iron contained:—

Silicon	1·671	
Carbon combined	0·936	3·352
" graphitic	2·416	
Manganese	3·080	
Sulphur	0·016	
Phosphorus	0·062	
Copper	0·100	
Cobalt	0·083	
Iron	91·636	
	100·000	

And the slag had the following percentage composition:—

Silica	43·35
Alumina	5·50
Lime	15·96
Magnesia	29·83
Protoxide of Iron	0·90
" of Manganese	2·70
Sulphur	0·23
	98·47

A wood cut and description of the Mariazell blast furnace, by J. Stummer Trauenfels, will be found in *Engineering* for August 29, 1873.

The present cost of producing one ton of best quality charcoal iron in Austria (Styria or Carinthia) is given in *Engineering*, August 8, 1873, as follows:—

	Grey Bessemer Pig.		White Puddle Iron.
Calcined ores with 48 to 50 % of iron	£2 1 0	...	£2 1 0
Limestone	1 7	...	1 7
Charcoal	4 7 6	...	3 10 0
Labour	10 2	...	6 8
Material, sundries, &c.	4 7	...	2 9
Management	2 11	...	1 2
	£7 9 7	...	£6 4 9

An illustrated description of the Neuberg Steel Works, in Styria, will be found in the numbers of *The Engineer* for June 13 and 27, 1873.

Besides the publications already mentioned in connection with the Vienna Exhibition, we have to notice the following:—

Bodmer-Mittheilungen ueber das mechanische Puddeln nach Danks. 2te. Heft, Suppliment-Bericht ueber das Danks'che Puddeln.—M 1, Lith-taf, gr. 8vo. Wien Lehmann and Wentzel. (A Supplementary Report on Danks's mechanical puddling system.)

Belgium.—Since the publication of our last report, the continental meeting of the Iron and Steel Institute has been held,. in August, in Liége, with such pronounced success, that the event may literally be regarded as the inauguration of a new era in the history of the iron and steel industries of Europe. This meeting, besides being an announcement to the world of the cosmopolitan character of the Iron and Steel Institute itself, as well as the first occasion upon which the representatives of the British manufacturers could come into personal contact with those of Belgium and many other parts of Europe, who had come to Liége for the meeting,

has, by its brilliant success, also proved that the time has arrived when it is at last acknowledged that the interests of the individual manufacturer in all countries is most intimately connected with the scientific and practical development of the industries themselves as a whole, and that to shut himself up within the walls of his works, isolated from the rest of the world, is infinitely less to his advantage than to trust to his own merits and enter boldly into the lists of friendly rivalry with his competitors. That this spirit animated the ironmasters and engineers of Belgium, when they invited the members of the Iron and Steel Institute to hold their annual meeting in Liége, with a view to a mutual interchange of ideas relating to these industries, was thoroughly demonstrated on the occasion of the August meeting, and the numerous excursions made to the surrounding metallurgical and mining establishments, which, in the most liberal manner, were thrown open to the inspection of the members. It was, indeed, a happy thought which suggested that Belgium should be the first country to welcome the Iron and Steel Institute to the continent of Europe, since this country, apart from the political and commercial relations which have long allied it to Great Britain, was in the fortunate position of a neutral ground during the disastrous war which so lately raged on the Continent. We must refer elsewhere for an account of the meeting itself, with its pleasant excursions, brilliant fêtes, and the lavish hospitality with which the city of Liége, the great establishments in its vicinity, and even His Majesty the King, at Brussels, entertained the members of the Institute, but we cannot refrain from alluding to the unmistakeable cordiality of a reception which above all made the members of the Institute carry home with them to England the most pleasing souvenirs of their Belgian friends and hosts.

As an iron producing country, Belgium now ranks fourth in Europe, and fifth in the world; Great Britain taking the lead, followed at an immense distance by the United States of America, and then by Germany or France, the last country having probably lost its position since the annexation of Alsace and Lorraine to Germany; Belgium follows close on their heels, and, with the exception of the above-mentioned, still has a production of more than double that of any other country in the world. The extraordinary rapidity with which the Belgian iron manufacture has developed itself of

late years, is well seen in the case of the Charleroi basin, which, in 1842, produced 40,000 tons of pig iron; in 1852, 81,821 tons; in 1862, 199,790 tons, and in 1872, attained the large amount of 400,000 tons,—thus, in other words, increased 218 per cent. in the first decade, 499 per cent. in the second decade, and no less than 1,000 per cent. in its third decade. Nor did the manufacture of wrought iron remain in arrear of the cast iron production, as, whilst in 1842 it was only represented by 20,000 tons, it became, in 1852, 37,326 tons; in 1862, 112,290 tons, and in 1872, about 250,000 tons, which figures show an increase in production of 177 per cent. on the first decade, 534 per cent. on the second, and as much as 1,190 per cent. on the third decade.

The state of the Belgian iron trade during the last half-year, 1873, has been extremely unsatisfactory, notwithstanding that the production both of the blast furnaces and rolling mills has been greatly restricted; up to date there appears but little hope of improvement. The steel trade, however, has not suffered in nearly the same degree, and the production of steel is, on the whole, being increased; it is reported that the Société de Sclessin, have applied one of their blast furnaces to the production of Bessemer pig iron. Amongst the blast furnaces blown out on account of the bad state of the iron trade, may be mentioned: on the 5th August, one blast furnace by the Société du Midi de Charleroi, on the 17th August, the Société Anonyme de Couillet also put out one; in October, two are reported as having stopped working, one at the Acoz works, and one at Messrs. Bonehill frères at Hourpes; in November, the Société de Montigny and the Société du Midi de Charleroi each blew out another furnace, and it is announced that out of the 30 blast furnaces in the Charleroi district, only 20 remain in operation, whilst in the Liége group, pig iron is accumulating; according to the last accounts in December, the Forges de la Providence have also put out one blast furnace.

From the Bulletin de l'Union des Charbonnages, &c., de la Province de Liége, we learn that the Belgium iron trade, taking into consideration its increased proportions, has of late become more and more dependent upon Luxembourg and other countries for its supply of ores; the reason assigned for which is, that the mining laws of Belgium do not favour the development of its minerals; the official documents showing the quantities of iron

ores actually raised in Belgium in the below-mentioned years to be as follows:—

Years.	Metrical Tons.
1865	1,018,231
1867	682,829
1868	519,740
1869	628,046
1870	653,332

And from the same source we observe the exportation of pig iron to have been:—

Year.	Metrical Tons.	Year.	Metrical Tons.
1863	22,913	1868	16,525
1864	25,957	1869	14,266
1865	10,711	1870	10,176
1866	15,271	1871	48,471
1867	11,061	1872	49,280

and 1873 first 10 months, 21,701 tons.

The great increase shown in the years 1871 and 1872 is quite accidental, being due entirely to the Franco-German war.

During the same years the importations into Belgium of pig iron from England, France, and Germany, are given as follows:—

Year.	FRANCE. Metrical Tons.	GERMANY. Metrical Tons.	ENGLAND. Metrical Tons.
1863	12 ...	1,451 ...	7,081
1864	68 ...	941 ...	7,497
1865	86 ...	403 ...	24,499
1866	565 ...	2,001 ...	29,627
1867	372 ...	2,343 ...	50,215
1868	311 ...	1,536 ...	41,532
1869	306 ...	864 ...	59,507
1870	314 ...	664 ...	79,966
1871	460 ...	1,833 ...	82,701
1872	3,996 ...	11,574 ...	120,916
1873 (ten months)	6,682 ...	8,237 ...	115,935

From the official returns of the imports and exports of this country, published by the Ministry of Finance, we have abstracted the following figures, which show the statistical condition of the

Belgian iron trade for the first ten months of 1873 as compared with the corresponding periods of the two preceding years :—

IRON ORES.

Countries.	Importation.—Metrical Tons. 1873.	1872.	1871.	Exportation.—Metrical Tons 1873.	1872.	1871.
Germany	426,308	470,018	399,948	31,957	37,212	58,443
Netherlands	8,903	12,386	8,248	53,812	32,250	—
England	380	624	—	90	—	—
France	179,099	213,010	97,813	107,959	80,319	81,601
Spain	10,013	6,474	1,012	—	—	—
Sweden and Norway ...	755	14	1	--	—	—
Algeria	808	264	—	—	—	—
Total	629,414	703,278	507,022	193,819	149,781	140,045

CAST AND WROUGHT IRON OF ALL DESCRIPTIONS.

Pig and scrap iron	133,455	115,089	72,677	21,701	43,760	39,177
Castings	998	816	732	4,626	3,662	2,619
Rails	8,912	2,637	195	57,416	69,122	73,867
Plate and sheet iron ...	1,395	439	132	16,079	20,047	16,773
Iron wire	1,882	2,432	819	68,777	80,318	66,554
Other wrought iron Bar iron	4,095	2,996	2,161	1,862	2,246	1,854
Nails	429	269	169	7,662	11,692	11,439
Other manufactured wrought iron ...	3,135	2,408	1,861	13,366	12,320	8,053
Total	154,304	128,982	78,758	191,493	243,170	220,339

We would here draw attention to a clerical error which occurred in the tabular statement of the imports and exports for 1872, as given in our last report; in this table, the quantities, instead of being noted as kilogrammes, are erroneously headed metrical tons.

The Chamber of Commerce, of Namur, has published its general report for the year 1872, from which it will be seen that in that year the province possessed six charcoal blast furnaces, of which only one was in operation, along with four coke furnaces, of which three were kept in blast. These furnaces employed 245 workmen, and turned out 41,740 tons of pig iron, which was 5,621 tons more than in the preceding year. The blast furnaces of Thy-le-Château produced 29,660 tons refining pig; Hainiau (Marche les Dames) made 10,600 tons refining pig; and the Couvin works turned out 1,095 tons charcoal pig. The rolling mills of Thy-le-Château furnished 32,850 tons of rails.

The annual meeting of the Société John Cockerill, at Seraing, took place on the 22nd October, when a dividend of 150 francs per

share was declared. The total value of the sales during the year 1872-1873, had risen to 25½ millions of francs, or above £1,000,000, it having previously been 15 millions in 1866, 18 millions in 1870, and 20 millions in 1872. Of this total, the steel manufactory had given more than 6 millions of francs, whilst the workshops and blast furnaces had doubled their production; one blast furnace had been specially constructed to smelt the ores from the company's mine, in Spain. It is in contemplation to erect a third group of puddling furnaces, notwithstanding that from the scarcity of workmen only 30 out of the 54 furnaces belonging to the company could be kept in work during the summer season. Notwithstanding the want of hands, which is estimated at some 1,500 less than could have been employed, the actual number of workmen in the service of the company, on the 30th June, 1873, amounted to 8,810. A description of the Seraing works of this company will be found in *Engineering* for September 26th, 1873. The Société Laminoirs de Châtelet held their annual meeting on the 23rd of October, and declared a dividend of 52·9 francs on the preference, and 27·9 francs on the ordinary shares of the company. The Société Anonyme métallurgique Austro-belge were not able to declare any dividend at their annual meeting.

Amongst the new Belgian companies we note the following:—

Société Anonyme Métallurgique et Charbonnière Belge, incorporated by a royal decree of the 18th May, 1873, for 30 years dating from the 15th May, with the object of acquiring and working collieries, coke ovens, blast furnaces, forges and rolling mills.

The Société Anonyme des Forges et Laminoirs de Marchienne-au-Pont was incorporated by a royal decree of the 24th May, 1873.

By a royal decree of the 30th September, 1873, M. Charles Delloye-Matthieu is authorised to add to the Marche Iron Works at Marchin, three puddling and four other furnaces, four trains of plate rolls, and the necessary engine power.

Société Thomas, Frères, for carrying on iron forges, at Brussels, for ten years, with a capital of 63,800 francs.

Société Anonyme des Hauts-Fourneaux de Monceau-sur-Sambre, at Brussels, for a term of thirty years, and with a capital of three million francs divided into 6,000 shares of 500 francs each.

Société Anonyme de la Fabrique de fer de Charleroi, with head quarters at Marchienne-au-Pont. The capital to be 1,100,000

francs in 2,200 shares of 500 francs each, and power to issue debentures to the amount of half a million francs.

In the *Revue Universelle des Mines*, vol. xxxiv., pp. 287-298, will be found a description with drawings of the charcoal blast furnace and refinery of the Couvin Iron Works in the L'Entre-Sambre-et-Meuse district, which is now the only existing blast furnace in Belgium worked by charcoal.

Brazil.—Immense deposits of magnetic iron ore of the richest class are reported to have been discovered in Province of St. Paul, at a distance of only some 8,250 metres from the river Jacripiranga, at a point where flat-bottomed steamers can ascend to. Limestone of a bituminous character, supposed to be indicative of coal, is found in the vicinity, and the whole of the country is covered with virgin forests. An imperial decree concedes these mines to Don Joachim Ignacio Silveira da Motta, and grants permission to found a colony and occupy the land at an extremely low price.

Burmah.—From the report of Captain G. A. Strover, political agent, Mandalay, on the mineral resources of Upper Burmah, published by order of the Government of India, we learn that iron ores occur in abundance in the Shan States, especially in the district of Pagan, south of Mandalay, where it is smelted in a rude manner and on a small scale at Pohpah Toung. Westwards of Sagaing, for miles up the Irrawaddy river, rich hematite iron ore is found in great quantity, and the Burmese government are now awaiting the necessary machinery and materials from England, for erecting works at Sagaing, for smelting the hematite, it being expected that the surface ore will fully supply these works for years in advance, without mining being resorted to. Limestone is found in abundance, and coal is known to occur in several parts of the Shan States, especially at Meimbaloung, where the deposit has been inspected by a mining engineer and reported to be equal to the best English coal in quality, and to pertain to the true carboniferous formation.

It is proposed to erect new iron and steel works on the right bank of the river Irrawaddy, about twelve miles below Mandalay; these will contain two blast furnaces, forge and rolling mill, and steel works for making crucible cast steel. The blast furnaces are proposed to be 56 feet high by 12 feet diameter at the boshes, iron-cased, and with arrangements for heating the boilers and blast by

the furnace gases; the blowing engines are vertical direct action, having 62-inch blowing cylinders, with 4-feet stroke to run at 40 strokes per minute—these engines are being made by Mr. J. Farmer, of Salford, whilst the rolling mill and forge fittings are by Messrs. Claridge, North, & Co., of Bilston, and comprise a forge train, merchant train, sheet mill, and mill for smaller sections. The management of the works is, we understand, entrusted to Mr. Robert H. Holgate.

Canada.—It is announced that a company has recently been formed for the purchase of the Haycock iron mines, near Toronto. It is in contemplation to erect blast furnaces and Bessemer converters for making steel, Mr. Holley's estimate of making Bessemer steel being £8 per ton.

A proposition has just been made to the inhabitants of Ottawa, to erect steel works there, which will employ 400 workmen, and require a capital of £100,000; the town of Ottawa being asked to find the ground with buildings, worth together about £30,000.

The recent report of Mr. Richardson, the Dominion Geological Surveyor in Vancouver's Island, shows that there is an apparently inexhaustible supply of iron ore in that district, especially on Texada Island, where enormous deposits of the richest and purest iron ores are stated to occur. As excellent limestone occurs in abundance in their immediate vicinity, and extensive beds of bituminous coal are close at hand, there would appear to be every element at hand required for the successful establishment of the iron manufacture in this colony.

China.—Some information on the state of the iron manufacture in this country may be gleaned from the inspection of a series of specimens of the ores and manufactured products contained in the Chinese department of the Vienna Exhibition, exhibited by M. Prosper Giquel, the manager of the Imperial arsenal at Fu-tschew, in the province of Fu-Kian, in the south of China, who at the same time has afforded some information as to the mode of manufacture carried on in that province. The ore itself is magnetic oxide of iron in small grains, which are disseminated through the sand arising from the disintegration of the granitic rocks, which occur on the eastern slope of the Tajueling range of mountains, and are carried down by river action to the lower parts of the country, where they are washed in troughs by the natives until the lighter particles

are carried away and there remains dark-coloured sand, consisting chiefly of magnetic oxide of iron, in quantity amounting to about from $1\frac{1}{2}$ to 2 per cent. of the weight of the original sand. This sand is then smelted with charcoal in small tapering blast furnaces, made of refractory clay and bound together by iron rings, the blast being produced by wooden bellows worked by men, and the furnace fed with equal weights of iron ore and charcoal. The product obtained is a mass of crude iron, containing fragments of slag and charcoal, 500 lbs. of the iron sand only yielding about 150 lbs. of reduced iron, which, after being again treated in the same furnace with about half its weight of charcoal, becomes a bloom of more or less steely iron, weighing about 83 pounds. Whilst still hot, this bloom is hammered down into bars of about one inch square, which, when cut across into lengths of six inches each, are ready for the market, and are sold to the arsenal, at Fu-tschew, at a price of about £11 per metrical ton (2,205 lbs. English). As the bloom of 83 lbs. only corresponds to about 17 per cent. of the weight of the iron sand employed in the first instance, it is evident that there must be an enormous loss of iron in this process, since the iron sand itself cannot be estimated as containing less than between 50 and 60 per cent. of metallic iron. It appears, however, that the Chinese Government, following the example of that of Burmah, are about introducing important reforms in the iron metallurgy of the Celestial Empire, as they have had a mandarin engaged this last summer in studying the iron manufacture in the United States of America.

France.—If we are to judge from the speech made in November, at Lyons, by M. Desseilligny, the Minister of Commerce, after his recent tour amongst the French ironworks of the southern and central districts, there seems to prevail a very high opinion as to their future capabilities, the Minister declaring that they were then in a position to compete successfully with England, and that this favourable state of things ought to encourage them in their efforts to conquer a predominating position in all the markets of the world. He considered the main element to be improved means of communication, especially by inland navigation, and, referring to the Loire iron mining district, which last year had turned out four millions of tons, considered that this might and would be doubled.

The official returns for the first ten months of this year show that 637,956 tons of iron ore was imported during this period, of

which 99,590 tons were from the Belgian frontier, 163,519 tons from Spain, 232,805 tons from Algeria, and 111,686 tons from Italy; the whole quantity shows an increase of some 66,000 tons, or about eleven and a-half per cent. over the corresponding period in 1872, which increase is entirely due to the larger importations of ores intended for the manufacture of steel. The imports of metals amount to 108,938 tons of pig iron, 41,109 tons wrought iron, and 5,500 tons steel; the total imports of pig iron show a diminution of 1,213 tons, or about one per cent. as compared with the same period in 1872, whilst the quantity of wrought iron was also less by 1,808 tons, or nearly four and a-half per cent. The total exports amounted to 208,693 tons, of which quantity 126,431 tons are the direct ordinary exports, the remaining 82,262 tons being sent out under the special decree which admits pig iron, &c., duty free for manufacture and subsequent re-exportation. The exports, under the above-mentioned decree, show an increase on those of the corresponding period of last year of more than 9,000 tons, or about 11 per cent., whilst the ordinary exports, on the contrary, are 6,970 tons or 5·3 per cent. less. From the above figures it would appear that the exportation of French iron has remained about the same as during the previous year, but that less foreign iron has been imported in the same period of the current year.

The French iron trade as a whole has not been in a satisfactory condition the latter half of this year, which generally has been marked by stagnation rather than activity. In the first half-year, 1873, seventy blast furnaces were kept in operation in the Haute-Marne district, of which 22 were driven by charcoal, 10 by coke, and 38 by a mixture of both fuels; 12 rolling mills, and 6 hammer-works employed collectively 100 puddling and 46 re-heating furnaces, besides 3 refinery and 9 re-heating hearths. The metallurgical production of the Haute-Marne district for the year 1872 is returned as follows:—Pig iron, 7,400 tons; castings direct from the blast furnace, 9,200 tons; castings from re-melting, 10,000 tons; rolled iron, 7,200 tons; hammered iron 8,000 tons, and iron wire 8,000 tons. In May, the large blast furnace erected by M. Desforges, at Marmaval-Saint-Dizier, was blown in, and is the first furnace of this size in the Saint-Dizier district; when in full work, its capacity is estimated at 280 tons per week, whilst the largest furnaces of Champagne do not produce

more than from 140 to 175 tons per week ; it is provided with an improved Cowper's apparatus for heating the blast, and is intended for the production of grey foundry pig iron.

La Compagnie des fonderies et forges de Châtillon et Commentry are erecting at Beaucaire extensive iron works with blast furnaces, which are expected to employ several thousand workmen, and two blast furnaces are being put up at the Pompey Works of M.M. Dupont et Dreyfuss.

A new rolling mill for sheet iron was started in June by M. Rodelet, at Marpont, near Jeumont, and the Liverdun forges commenced work on the 1st October.

The Société Michel Helson et Cie, at Hautmont, Nord, at the annual meeting of the 19th August, decided to erect a second blast furnace, as also a new rolling mill for sheets and special irons, and in November a new company, with head-quarters at Lyons, and a capital of 1,800,000 francs was formed to purchase and work the blast furnace of Chosse (department of Isère) and the mines of Elm-Kimen in Algeria.

The following companies have declared dividends:—Société de fonderies et forges de Pont l'Eveque, 24th October, 60 francs per share ; Aciéries et forges de Saint Etienne, 25th October, 40 francs per share; and the Fonderies et forges de l'Horme, 6th November, the very high dividend of 120 francs per share.

The great works of M.M. Schneider & Co., at Creuzot, have continued in full activity, apparently quite unaffected by the depression which has ruled amongst the other establishments in general. In order to secure a full supply of high class iron ores, they have recently purchased the mines of Beni-Susuf and Gar-el-Baroud, in the province of Oran, in Algeria, as well as made arrangements for the produce of various other iron mines in France and Savoy. It is reported that some 15,500 workmen are now employed at their mines, mills, and furnaces, which annually turn out 50,000 tons steel rails, 20,000 tons iron rails, and about 100 locomotives, from the workshops; 12 blast furnaces are kept in operation to supply the pig iron required for the Bessemer and other works.

At a general meeting of the shareholders of the Usine de Creusot, held on the 29th November, a dividend of 50 francs per share was declared for the half-year, a second dividend to be paid on the 15th June, 1874. It was announced that the sales had increased from

55 millions of francs in 1871, and 76 millions in 1872, to 90 millions in 1873. At an extraordinary meeting, held on the same occasion, it was decided to increase the capital from 18 millions of francs, now represented by 36,000 shares, to 27 millions, divided into 75,000 shares.

The steel manufacture in France has gone on steadily progressing, and but little affected by the slackness in the iron trade, as is shown by the quantity of ores suited for steel making now imported, and which, in the first six months of this year, was no less than 40 per cent. more than in the corresponding period of 1872. A company with a capital of two millions of francs was formed, in September, in Paris, for manufacturing steel by Gallet's process.

The Western of France Railway Company, which, up to the close of 1872, had laid down steel rails for more than 146 miles, are extending their employment still further.

The following new works have appeared in Paris:—

Jullien, C. E. Introduction à l'étude de la metallurgie du fer. Dernier mémoire publié en Janvier, 1873. Annexe au Traité théorique et pratique de la metallurgie du fer. Paris-Baudry. (Introduction to the study of the metallurgy of iron).

Jordan, S. Notes sur la fabrication de l'acier Bessemer, aux Etats-Unis d'aprés. MM. Holley, Smith, &c. Paris, Lacroix, 7 frcs.—1873. (Notes on the manufacture of Bessemer steel in the United States.) Extrait des memoires de la Société des Ingénieurs civils.

Germany.—The technical journals of this country, although usually so rich in data for forming a sketch of the progress made in the iron and steel manufacture of the Empire, have during the past months been quite the reverse. In the Berg-und Huetten-Mænnische Zeitung, for the 12th September, will be found a paper on the iron mines of Upper Silesia, and their system of working, by B. Turley, which, however, does not possess any features of interest for the English ironmaster.

From a description of the celebrated steel works of M. Krupp, at Essen, we extract the following particulars:—These works, which at the commencement of this year covered a continuous area of about 1,000 acres, of which 200 acres are under roofing, along with the mines, give employment to about 17,000 workmen, exclusive of 739 foremen and employés, who are in part lodged in 2,948 houses, besides 266 dwellings for the employés, and two hospitals, one with 100, and the other, for infectious diseases, with

120 beds. A body of 166 watchmen, and a permanent fire-brigade of 70 men, who also perform police duty, are employed. The commissariat department has under it—one hotel, three beer-houses, one seltzer water manufactory, a flour mill and a bakery, containing two steam engines, besides extensive general supply stores, where all connected with the works can purchase, for cash, provisions, clothing, dry goods, &c., at cost prices. There are also a chemical laboratory, photographic, lithographic, and bookbinding establishments, as well as a printing-office, which employs two steam and four hand presses. A sick, burial, and pension fund has been instituted, to which M. Krupp contributes half as much as the workmen ; the annual receipts of this fund amounted in 1872 to £16,000—another fund provides medical treatment to its members on payment of three shillings per head annually.

The number of mines belonging to the works is 414, covering an area of some 50,000 acres, besides which, mines in the North of Spain have been recently acquired, from which an annual supply of some 300,000 tons of ore, suitable for steel making, are expected, as soon as the railway, nearly eight miles in length, now in course of construction (as well as several steamers) is completed.

One hundred and forty coke ovens are in work, and 120 additional in course of construction, these supply eleven blast furnaces with fuel, which turn out nearly 10,000 tons of pig iron per month.

In 1872, the works consumed 500,000 tons of coal, 125,000 tons coke, and 113 million cubic feet of water, whilst the gas works on the premises supplied 155 million cubic feet of gas through 16,500 burners.

To facilitate the traffic in the works, there are about 24 miles of usual gauge railway track, with 180 sidings and 39 turntables, which are worked by 12 tank locomotives with 16 inch cylinders and 530 wagons. Ten miles of narrow 2 feet 6 inches gauge track, with 147 sidings and 65 turntables, are also worked by three locomotives with 6 inch cylinders and 270 cars ; and in addition 191 horses are employed. Communication between the various parts of the works is maintained by thirty telegraph stations.

The works themselves contain 250 smelting furnaces of various descriptions, 390 annealing do., 161 re-heating do., 115 welding and puddling furnaces, 14 cupolas, and 160 furnaces of other kinds,

besides 275 coke ovens, 264 smiths' forges, and 240 steam boilers.

In the workshops are to be seen 286 steam engines, 71 steam hammers, 362 lathes, 82 shaping machines, 195 boring do., 107 planing do., 42 punching and grooving do., 32 pressing do., 63 grinding do., 31 glazing and polishing do., and 142 other miscellaneous machines.

The quantity of cast steel made in these works in 1872 exceeded 125,000 tons, in the shape of axles, tyres, railway wheels, crossings, rails and springs, shafts, artillery shot and shell, boiler plates, &c., the quality of which are too well known to require any comment, and many of which were well represented at the Vienna Exhibition, particularly in the case of artillery.

Drawings and description of a pair of powerful blowing engines, made by Messrs. Galloway for these works, will be found in *The Engineer* for November 21, 1873. These steel works were lately insured against fire in some twelve German offices for the sum of 6,513,306 Prussian thalers, or not much less than one million sterling.

It is reported that M. Krupp has made known that any workman or employé at the steel works who may take part in the discussion of the religious questions now causing so much trouble in Germany will be immediately dismissed.

The Prussian Mining and Ironworks Company held their ordinary general meeting of shareholders, at Dusseldorf, on the 6th December, Mr. Wm. T. Mulvany, the President, in the chair; a dividend of £3 18s., or at the rate of 13 per cent. on the capital, for the business year 1872-3, was declared, and it was announced that the directors, with the sanction of the council of supervision, have acquired for the company the Teutonia Blast Furnace, near Willebadefaen, in Westphalia, with extensive oolitic ironstone mines, various brown hematite mines in Thuringia, Oberhessen, Sauerland, shares in a spathose ore mine near Siegen, and a mine of magnetic iron ore in the Hardanger Fjord, in Norway.

The New Essen Mineral Company declared a dividend for 1872 of 30 per cent. on the capital of the company.

The German company which took over the Forges de Lorraine from MM. Dupont et Dreyfuss, of Ars sur Moselle, have held, in December, their first general meeting, under the presidency of

Count G. Henckel de Donnersmarck. From the report, which only takes in the first four months of the company's existence, from March 1st to June 30th, 1873, we extract the following particulars:— The purchase sum amounted to 15 millions of francs, besides 142,368 francs for lands, &c., and the stock of metals, &c., taken over by the company, amounting to 2,234,117 francs. During the four months the production amounted to: Iron ores, 534,680 cwts.; coke, 224,800 cwts.; puddled iron, 218,000 cwts.; rolled iron, 107,620 cwts.; other irons, 8,680 cwts.; whilst the sales during the same time were 62,280 cwts., of a total value of 2,390,087 francs. The gross profit made was 775,318 francs, from which, after deducting management, interest, amortization, &c., there remained a net profit of 396,682 francs.

The prospectus of a new company entitled the "Westfaelische Union," with a share capital of three and a-half million Prussian thalers, about £525,000, has been issued for the purpose of acquiring the ironworks of Cosack and Co., in Hamm; Edw. Schmidt, in Nachrodt; and A. et E. Lenhoff, in Lippstadt; which collectively contain 1 charcoal blast furnace, 63 puddling furnaces, 19 re-heating furnaces, 22 trains of rolls, with steam hammers, &c., and iron mines, and the present production of which is stated to be about 35,000 tons annually of wrought iron of all descriptions, in the form of bar, plate, wire, axles, bolts, &c.

In the German department of the Vienna Exhibition, besides the steel artillery, &c., contained in the Krupp pavilion, there was a series of iron ores and metallurgical products from Westphalia, and a good collection of rails, bars, and plates, from various German ironworks, especially the Kœnigs and Laura Works, the Borsig works, in Upper Silesia, and the Burbacher Iron Works, near Saarbrueck; but nothing of a decidedly novel character. A rolling mill engine, exhibited by Messrs. Elgbirth and Cunzer, of Eschweiler-Aue, in Rhenish Prussia, will be found described with illustrations in *Engineering* for June 27th, 1873.

The following works have appeared since the publication of our last report:—

Eisenhuettenkunde, II., Bd. 8 lief. v. Dr. H. Wedding, Braunschweig. Vieweg und Sohn, 1873. (The metallurgy of iron, being the concluding part of the second vol. of the excellent translation of Percy's metallurgy by the able Professor of iron metallurgy in the Berlin School of Mines.)

Bericht ueber die Fortschritte der Eisenhuetten-Technik im Jahr, 1870, von Professor Auton Kerpely, mit 8 Tafeln. Leipzig, Arthur Felix. (Report on the advances made in iron smelting in 1870, highly to be recommended.)

Beschreibung der Verhaeltnisse u. Einrichtungen der Georgs-Marienhuette zu Osnabrueck, mit 6 Tafeln, gr. folio. Hannover, Schmorl and v. Seefeld, 1873. (Description of the Georgs-Marien Iron Works, at Osnabrueck.)

Kupelwieser u. Schœffel Beitrage zum Studium des Hohofen-Processes. Wien. Beck'sche Univ.-Buchh. gr. 8vo. (Contributions to the study of the blast furnace process.)

Kerpely, Die Anlage u. Einrichtung der Eisenhuetten, mit Atlas; Leipzig. Felix, 1873. (The construction and arrangement of ironworks.)

Ziebarth Gewichtstabellen fuer Walzeisen-Berlin. Rudolph Gaertner. (Tables of the weights of rolled iron.)

Greece.—It is a considerable time since we have been able to communicate any information as to the iron mines or metallurgy of this country; it appears, however, from the recent number of the *Levant Herald*, that the Hellenic Mining Company has contracted for the exportation to England, of large quantities of rich iron ore from its mines in the island of Seriphos; it is also stated that the large works erected by Tubiné, near Newcastle, under the name of the Royal Greek Iron Works, for smelting these ores, have commenced operations.

India.—As giving a very good summary of what is known about the modern attempts at iron making in British India, we have been induced to reproduce the following remarks from the *Times* of September 8th, 1873:—" Iron producing minerals are widely scattered over India. There are magnetic and specular iron ores and red hematite in beds and veins; there are clay iron ores from the coal-bearing strata; and there are surface deposits derived from the waste of metamorphic and sedimentary strata, and from laterite. The latter formation contains from 20 to 30 per cent. of iron. Some of the most remarkable deposits of magnetic iron ores are in the Salem district of the Madras Presidency. The ores occur in immense beds, 50 to 100 feet thick, and the outcrop may be traced for miles. On one hill, six miles from Salem, there are five bands of magnetic iron from 20ft. to 50ft. thick. At Lohára, in the Chanda district of the Central Provinces, there is a hill two miles long and half a mile broad, the surface of which is covered with masses of almost pure iron ore. In Bandalkhand and in the Narbada valley there are large quantities of hematite ores; the supply in many cases is practically inexhaustible. The clay iron ores in

the Raniganj and other Damuda coalfields yield 39 per cent. of iron. The Kamaun iron ores form an argillaceous band, containing large quantities of red hematite, the ore bed being 10ft. to 20ft. thick, and extending for a long distance. The surface deposits supply the greater proportion of ores used by native smelters, but much labour is necessary in the collection. Iron has been manufactured in India from time immemorial, and iron weapons are found in the ancient cromlechs and kistvaens, but there never were any large works. The production of iron is the work of poor people of very low caste, scattered over the country. They have small clay furnaces, with charcoal for fuel, and the blast caused by foot or hand bellows. The smelting goes on for eight or ten hours, at the end of which time from 10lb. to 20lb. weight of iron is found at the bottom of the furnace; this is purified by reheating and hammering, and the resulting iron is generally of excellent quality; but the native manufacture is rapidly decreasing, owing to the difficulty of obtaining charcoal. All attempts by the English to manufacture iron-in India have hitherto utterly failed. In 1825 Mr. Heath, of the Madras Civil Service, obtained a Government advance, and formed a company to establish iron works at Porto Nova, near Cuddalor; at Polamputi, near Salem; and at Bepur, where the iron was obtained from laterite; but the result was nothing but failure, attributed partly to the distance of the works from the source of supply and to the scarcity of charcoal. In 1857, Mr. Sowerby, an engineer, reported on the iron ores in Kamaun, but repeated attempts to work them ended in financial failure; and a similar attempt by a Calcutta merchant, who started works near Suri, in Birbhum, was also abandoned. The enterprise of the Goverment in the Narbada Valley promised well, and might have been most successful. Works were erected at Burwai, on the Narbada, under the auspices of Colonel Keatinge; Mr. Mitander, a very able Swedish metallurgist, was induced to take charge of the works, and after many experiments all difficulties were overcome, and the works were ready for the production of iron. Suddenly, in 1864, the Government, after spending £75,000 on these preliminary expenses, dismissed Mr. Mitander, closed the works, and offered them for sale, without success. They have now, with the ground on which they stand, been made over to Holkar. Iron ore and limestone abound in the neighbourhood; large forests, furnishing

supplies of charcoal, extended for many miles to the east and north-east; and Mr. Mitander was an excellent manager. No record has even been preserved of his experiments and plans for burning and storing charcoal and for other processes, which would have been useful at a future time. This year's *Statement relating to India*, referring to these facts, notices that the Government are now once more anxious to foster the iron manufacturing industry of India. Last year Mr. Bauerman was sent out to report on the subject. The increased price of iron is most favourable to the prospect of the manufacture proving profitable in India. The use of Indian coal for smelting iron has never yet been tried.

ITALY.—From a report on the conditions of the mining industry, in the Island of Sardinia, by M. Sella, the Minister of Finance, a translation of which is to be found in the *Revue Universelle des Mines*, vol. 33, we learn that veins of magnetic oxide of iron are abundant in several of the geological formations, but that their positions render cheap transport of the ore to a shipping port out of the question except in the single instance of the mines of Saint Léon, Capoterra, on the Gulf of Cagliari, which were in 1861 purchased by the French company, Petin-Gaudet et Cie, for the sum of 29,000 francs, along with an annual payment of 1,360 francs, and in 1863 obtained the definite concession over 360 hectares, or nearly 900 acres. An analysis of the ore was given in our second report for 1872.

The lode or lodes, for there are two, known respectively under the names of Gaudin and Petit, have the direction of the magnetic meridian, and dip into the Silurian Slates to the westward; their outcrop is situated at a height of 400 metres above the level of the sea. The ore had consequently to be brought down by three different inclined planes following one another, and then by a railway to the shipping place in the bay; by these means some 240 to 300 tons per day could be shipped, but the arrangements were so expensive as to cost the company about one-and-a-half million francs before completion, and when the ore had to be mined out by regular workings underground, it was found that whilst the extraction of ore at the surface did not cost above two shillings per ton, it soon increased to about four times this amount, and the expense of placing the ore on board ship in the bay of Cagliari, without including the expense of management and general charges,

was found to be, according to data obtained from M. Gouin, the manager of the mine, as follows:—

Mining and extraction	9·24	francs per ton.
Transport by inclined planes ...	1·47	„ „
Do. by railway to the sea ...	3·75	„ „
Putting on board	1·90	„ „
Total	16·36	francs.

Which, in 1869, when the price of the iron ore on board ship at Cagliari was not more than from 9 to 11 francs per ton, according to its quality, was not found to pay, and consequently the workings, which employed some 300 men, were abandoned, at least for the time. It is reported that they have since been resumed, although M. Sella does not consider that they can possibly compete as to price with the iron ores from either Elba or Algeria.

Our attention has been directed to the following pamphlets not before noticed in our report:—

Lasagno. Cenni sull 'industria del ferro nelle provincie di Torino e Novara in confronto dell industria ferriera della Gran Brettagna. (A consideration of the iron manufacture in Northern Italy as compared to that of Great Britain.) Torino, 1872. tip Favala.

Miniera di ferro ossidulato manganesifero de Montaldo-Mondovi. (On the manganiferous oxide of iron of Montaldo-Mondovi.) Torino tip Botta. 1873.

Soppelti V. Stato attuale dell 'industria del ferro i Lombardia, et cenno sul possible Sviluppo della Siderurgia in Italia. Milano, 1873. (On the actual state of the iron manufacture in Lombardy, and on the possibility of developing the Italian iron industry.)

In the first ten months of this year, 111,686 tons of iron ore were exported from Italy to France.

Luxembourg.—A convention between the Government and the ironmasters of the Grand Duchy was entered into on the 19th May, by which these latter are conceded 333 hectares, about 830 acres, mineral lands, which are divided amongst the concessionaires as follows :—

	Hectares.
La Société Metz et Cie	80
„ Servais frères et Cie	50
„ Charles et Jules Collart ...	18
„ Philippe Servais Majeries et Cie...	15
„ des Hauts-fourneaux Luxembourgeois	80
„ P. Giraud et Cie	18
„ des Hauts-fourneaux de Rodange	36
„ Gouner, Munier Helson et Cie ...	36
Total ...	333

In return for these concessions are obliged to pay to the Government, during fifty consecutive years, a rent of 250,000 francs, divided amongst the concessionaires in the proportion of the area of the land they respectively hold; the first payment to take place on the 31st December, 1874, and the last on the 31st December, 1923. The above convention was confirmed in the Chamber on the 20th August, 1873.

The Société des forges et laminoir de Luxembourg have put their rolling mills in work, commencing with the puddling train in June, and the merchant bar rolls in September. A new company, entitled Société Industrielle du Grand-Duché de Luxembourg, has been formed, in October, for the purchase of iron and coal mines, and the erection of blast furnaces, forges, coke ovens, &c.; the capital being five million francs, divided into shares of 500 francs each.

At the annual meeting of the Société des Hauts-fourneaux Luxembourgeois, on the 14th October, a dividend of 10 per cent. per share was declared, and it was announced that the company had acquired, without cost, three mineral concessions in Lorraine, containing an area of 196 hectares, or about 485 acres.

From a statement made by the Director-General of the Interior to the Chamber of Deputies, it appears that the extent of mineral lands explorable by levels, and subject to being conceded, is greater than was previously supposed; whilst, on the other hand, those explorable or open cuttings, and not subject to being conceded, is less than generally imagined; thus, according to the data furnished by M. Salenting, the total area of the mineral lands of Luxembourg amounts to 2,750 hectares or about 6,370 acres, excluding the basin of Dudelange, which, as yet, is not surveyed. Of these 2,750 hectares, 1,720 hectares are explorable by adit levels, and 1,030 can be developed as open cuttings; with respect to the former or concessible lands, the Société Prince-Henri obtained 400 hectares in 1869, as subvention for constructing railways, and 350 additional have more recently been granted for the same purpose; 333 hectares were, as already mentioned, granted to the Luxembourg ironmasters, which makes in all 1,110 hectares, so that there still remains 610 hectares disposable.

As a proof that in Luxembourg the ironmasters are not behind us, it may be mentioned that after the meeting of the Iron and

Steel Institute in Liége, several English ironmasters visited some of the new ironworks of this district, and saw, to their suprise, two large blast furnaces in operation with all the latest improvements known in the Cleveland district, and provided with far more powerful blowing engines, heating stoves, boiler power, and better distribution of the materials in the furnaces than can be found at Middlesbrough. The furnaces are 65 feet high, and produce an average of 600 tons puddling iron per week. The ores are lean, containing only 30 per cent. metallic iron, and requiring 75 cwts. to be charged into the furnace for each ton of pig iron. The coke contains from 18 to 20 per cent. of ash, and yet only 21 cwts. coke is used to the ton of iron, whilst in Cleveland, with much better coke, the average is above 23 cwts., and the output of the furnaces do not come up to 400 tons per week.

New Zealand.—From this colony we learn that a company has at last been formed by Mr. Walduck, in England, for the purpose of smelting the Taranaki iron sand, which has so long been before the British public. On the authority of the *Manchester Guardian*, of the 4th October, we give the following information:—"A number of British ironmasters have just acquired nearly 20 square miles of property in the Wharekawa district, in the province of Auckland, New Zealand. The property embraces 8,700 acres of coal and ironstone. The chief seam of coal is found in some parts within a few yards of the surface as thick as 20 feet, and it is computed to be capable of yielding an average thickness of 10 feet throughout the whole 8,700 acres. This represents no less than 126,000,000 tons of good coal. The ironstone is of the brown hematite class, and contains as high a percentage as 62 of fine iron, and is believed to yield an average of 50 per cent. Four specimens reported upon on Thursday, after analysis by a metallurgical chemist in the Midlands, showed 60, 59, 50½, and 36 per cent. respectively. Calcined, it will be worth in this country—as prices are just at present—30s. per ton. Made into iron upon the estate, the coal and ironstone, estimated each at 8s. per ton, and the limestone, also found on the estate, at 7s., would enable a ton of hot blast pigs to be produced at £2 13s. per ton, and the quality would be equal to British iron which is now selling at £7. Made into cold blast iron, the cost would be about £2 17s. 6d., and the quality would be equal to the British iron which now realises £8 per ton."

RUSSIA.—The most recent information with respect to the iron manufacture of this country which we have come across, is contained in the Tableaux Statistiques de l' Industrie des Mines de la Russie, en 1871, published in connection with the Vienna Exhibition of this year, by M. Skaljkowsky; from there it appears that in 1871 the number of iron mines worked was 1,174, which turned out a total of 820,000 tons of ore, whilst in the same year the productions of the various smelting works amounted to 354,000 tons of pig iron, 30,000 tons castings, 241,500 tons wrought iron, and 7,000 tons of steel.

In the Vienna Exhibition, the iron manufactures of Russia are fairly represented. From the north, on the Gulf of Bothnia, samples of the so-called lake ores, a concretionary hydrated oxide of iron, often with considerable oxide of manganese, dredged up from the fresh water lakes, and of iron made from it, are exhibited from Tushby, Uliaborg, and Gamlekarlby; the district between Lake Ladoga and the Gulf of Finland shows white and mottled pig iron with plates, bar and angle iron of good quality, from the ironworks of Warschavsky & Co., at Raivolo, near Viborg, whilst a collection of the products of his ironworks are shown by Nicolas Poutiloff, of St. Petersburg, who employs some 4,000 men in the works, or, including those in the mines, carters, charcoal burners, &c., about 18,000 in all. The cannon foundry of Oboukhoff sends a few good specimens of steel guns and mortars, whilst samples of merchant bar and plate come from the Kamsk forges, on the Viatka river. The great works of Demidoff, at Nijni-Tagil, exhibit pure magnetic iron ores, clay ironstone, and pig iron of excellent quality, whilst the Rastorgouieff Trustees, from Ekatarinburg, have wrought iron, rough and polished plates and art castings. The Stenbock-Fermor Works, which have seven blast furnaces, supplied with magnetic iron ore from the famous mines of Mount Blagadd, send a model of the works and also bar and sheet iron and samples of the pine charcoal used in its manufacture.

The Imperial Cannon foundry, at Perm, shows a model of one of the largest anvil blocks ever made, as it weighs 622 tons, and is intended for a 50-ton double action steam hammer; some good specimens of steel and steel cannons, and shell, are also to be seen in the arms department, amongst which was observed an eleven-inch shell, which, after having penetrated an eleven-inch armour

plate, has sustained no other injury than having a small piece of the point broken off.

A collection of steel articles, as cutlery, &c., exhibited from Nijni-Novgorod, the Sheffield of Russia, do not come up to the English standard of finish, although probably the material is of excellent quality.

A Russian company has been formed for carrying on the very extensive works of M. Poutiloff, which consist of Bessemer converters, with rail rolling mills near St. Petersburg, puddling furnaces and rolling mill on the Nicolai Railway, and three ironworks in Finland, containing blast furnace, rolling mills, &c. The capital of the company is fixed at five million silver rubles, about £800,000, in shares, along with three million silver rubles, about £475,000, in 6 per cent. debentures.

In England, a limited company, entitled "Tiflis Iron Mines and Works," with a capital of £155,000, in shares of £100 each, was registered in September last, to acquire and work the Bolais Iron Mines and Iron Works, situated about 35 miles from Tiflis, in Asiatic Russia.

The ordinary general meeting of the Russian (Vyksounsky) Iron Works Company, Limited, was held in London on the 18th November, when a dividend of 15 per cent. for the past year was declared.

The following work has recently appeared, and gives a description of the deposits of magnetic and specular oxides of iron in the south of Russia:—

Suedrusslands Magneteisenstein und Eisenglanzlagerstaetten in den Gouvernements Ilkatherinosslau und Cherson. Von Leo Strippelmann. Halle. Knapp. 1873.

SPAIN.—The mineral and metallic statistics of this country are not only extremely behind-hand, but also when they are published are but little to be depended upon for accuracy; the official returns for the year 1870, which are of a very meagre character, have only been recently published by the Government, and will be found in the numbers of *La Mineria* for August 7th and 15th, 1873. From these tables it appears that whilst the number of concessions of iron mines in force on the 1st January, 1870, was 582, it had increased to 615 on the 31st December of the same year. During the year 1870, 267 iron mines had been kept in operation by a force of 2,479 men, 162 women, and 152 boys, with two steam engines of a

collective force of twelve horse-power, and a total yield of 4,365,861 metrical quintals of iron ore, which, reckoning the metrical quintal at 100 kilogs., will amount to 436,586 metrical tons.

The number of ironworks in operation in 1870 is reported as 75, with a production of 54,007 tons pig iron, and 36,162 tons wrought iron, and employing 3,570 men, 151 women, and 452 boys, along with 154 water-wheels, representing 1,549 horse-power, and 120 steam engines of 2,796 horse-power.

The abcve figures show that the production of the year 1870 has exceeded that returned for the preceding year by 125,240 tons of iron ore, 19,521 tons pig iron, and 536 tons wrought iron.

The Taco Steel Works, employing 16 men, and 4 water-wheels representing 80 horse-power, are reported as having been in operation in 1870, with a production of 231⅕ metrical tons of steel.

The exportations from Spain, in 1870, are returned as follows: 253,221 tons iron ore, 88 tons manufactured iron, 4,023 tons old rails, and nearly 19 tons bar steel. From other sources we learn that the exportation of iron ore to Great Britain, which, in 1868, was only 88,000 tons, had increased, in 1872, to 631,000 tons, and is still increasing largely. In the Berg und Huettenmænnische Zeitung, for Oct. 17th, a communication will be found, by Messrs. Roehrig and Hass, on the Bidasoa iron ores, in which special attention is directed to the removal of sulphur from these ores by washing them with water after a previous calcination. The ores themselves are spathic carbonates of iron containing manganese, and are quite free from phosphorus, so that, when the sulphur is eliminated, they are well suited for the production of Bessemer pig. A translation of this paper will be found in the *Chemical News* for October 31st, 1873.

A limited company, entitled the Orconera Iron Ore Company, has been registered with a capital of £200,000 divided into twenty shares of £10,000 each, for the purpose of acquiring and working iron mines at Somorrostro, near Bilbao, now in the hands of Messrs Ybarra & Co., as well as constructing a line of railway from the mines, which is to be called the Orconera and Luchana Railway. Another English limited company, with the name of the Santander Iron Ore Company, was registered in November, with a capital of

£80,000 divided into shares of £10 each, the object being to purchase and work iron mines near the town of Santander—the ore from which is said to exist in very large quantity, and to contain from 59 to 63 per cent. of metallic iron, with only a very small percentage of sulphur and but traces of phosphorus. This new company is in no way connected with the Santander Mining Company (Limited), which has been working iron mines in the same part of Spain during the last two years.

SWEDEN.—In the fourth number of Jern-Kontorets Annaler, for 1873, will be found the particulars of experiments made by Mr. A. Grill, at the Huseby Iron Works, in smelting with a mixture of Swedish coal, uncoked, with charcoal in the blast furnace. The Swedish coal belongs to the cretaceous formation, is, properly speaking, a lignite, and does not coke when heated. The results of the trial smeltings showed, although a very troublesome stiff slag was produced, that the iron was of good quality, and indicated that when a good slag-making flux is employed, the coal could be used in a small proportion with advantage.

The two new charcoal blast furnaces erected by the Central Swedish Iron and Steel Company, Limited, at Bjorneborg, were put in blast in October, on Bessemer pig iron, and are in most satisfactory working; it is expected that the Bessemer works attached to them will be ready early in 1874, when the steel will be run into the converters direct from the blast furnaces.

The Bongbro new Bessemer works, blast furnaces, and rolling mills, are being rapidly constructed, and will, it is expected, be very soon in partial operation.

At the Svartnaes Works, about 47 tons of Bessemer steel ingots are made per week direct from the charcoal blast furnace, which is a small one; this quantity of steel represents between 88 and 89 per cent. of the total iron produced by the blast furnace, and this very satisfactory result is attributed chiefly to the ample power of the two double action blowing cylinders, which are worked by two turbines, each of 175 horse-power; at the commencement and end of the blow a pressure of from 250 to 300 lines of mercury is employed (exceptionally even as much as from 320 to 350 lines), but during the rest of the blow from 120 to 180 lines is found sufficient. By the employment of so high a pressure and quantity of blast, the duration of the operation is lessened and the temperature

raised. The converters are lined with quartz, which stands some 60 or 70 blows.

An elaborate series of experiments made on the steel from the Fagersta Works, which fully bear out the good character of their products, has been published in quarto form, with numerous plates, by Mr. David Kirkaldy, entitled "Results of an experimental enquiry into the mechanical properties of Steel of different degrees of hardness, and under various conditions, manufactured by Christian Aspelin, Esq., Westanfors and Fagersta Works, Sweden. By David Kirkaldy. London, 1873."

In the Vienna Exhibition, a large cast iron breech-loading cannon of 24 centimetres calibre, with steel rings shrunk on it, is shown by the Finspong Iron Works, which have so long been known for their excellent cast iron artillery; from this gun 330 rounds had been fired, using 24 to 26 kilogs. of gunpowder, and an iron shot weighing 144 kilogs. Various other guns of smaller dimensions were also shown, and some surprise was expressed at the extremely low prices at which they could be delivered.

UNITED STATES.—The annual meeting of the American Iron and Steel Association took place on the 20th of November, at Philadelphia, under the presidency of Mr. Samuel J. Reeves; a large number of members attended, and, amongst others, the following resolutions were carried :—

Resolved—That this Association attributes the general prosperity of the iron trade of this country, which has characterised the past year and the previous years, to the tariff policy of the Government, which has fostered home industry, and enabled many branches of manufactures to obtain a position rendering them independent of foreign rivalry.

Resolved—That the manufacturers of iron and steel, in the United States, do not regard themselves as in any way responsible for the present embarrassment of their industry, which they have conducted with care and economy, and they are assured that the adoption, by Congress, of a financial system adequate to the largely increased and increasing business needs of the country, will enable them not only to supply all demands for home consumption, but also to rival older nations in the markets of the world.

Resolved—That the rapid and healthful growth of iron shipbuilding in this country has demonstrated the beneficial influence of the registry laws of the United States, and that, under their protection, American shipbuilders will be enabled, through the improvement and development of our manufactures of iron, to take possession of the carrying trade of the country, foreign as well as inland, thus adding greatly to the prosperity of the nation in peace, and to its strength and resources in time of war. We believe that free trade in ships would check this

wholesome progress—would be detrimental to American labour, and injurious to the best interests of the country.

Resolved—That this Association has learned, with great satisfaction, that the members of the Iron and Steel Institute of Great Britain propose to visit this country next year, for the purpose of ascertaining the extent and progress of the iron and steel industries of the United States, and that the members of this Association will extend to them a hearty welcome, and will take pleasure in showing them their several works, and in otherwise aiding them to accomplish the object of their visit.

Resolved—That the acceptance, by the Executive Committee, of the trust delegated to this Association by the Executive Committee of the United States Centennial Commission, of making an adequate representative collection of the iron ores of the United States, for display at the International Exhibition of 1876, is hereby approved ; and, recognising the importance and difficulty of the work, the Association asks the active co-operation of all manufacturers of iron and steel, and producers of iron ore, and it further invites assistance in the collection of samples of all the fuels, fluxes, and refractory materials used in the iron trade or likely to be of use to it.

A motion was also carried to the effect that the next meeting should be held in Philadelphia, on the 4th of February, 1874, and that the other Iron Associations be requested, through their Secretaries, to meet with the Iron and Steel Association on the following day.

The iron industry, which had been so wonderfully brisk in 1872, during which year no less than forty new furnaces had been put in blast, not counting others in course of construction, showed symptoms, at the commencement of this year, of a decline, both as regards consumption and prices, which gradually increased during the spring. At a meeting of the Amercian National Association of pig iron manufacturers, held on the 20th of June, at Cleveland, in Ohio, it was resolved, " That in the present condition of the iron trade of this country, it is desirable that the production of metal should be curtailed as far as possible, until a more favourable market is established, and that a copy of this resolution be sent to each member of the Association." Upon the receipt of this notice, a number of furnaces in the Mahoning and Shenango valleys were at once put out of blast, but the bad state of matters gradually became worse until the financial crisis of the 18th September took place and completely deranged the iron trade of the country, so that, in November, not only had the quoted prices of crude and manufactured iron fallen to nearly as low as they were in 1871, before the rise commenced, but the demand especially for

all classes of railroad iron had all but ceased. At the commencement of November, a large number of blast furnaces, bar mills, and rail mills, had stopped working, and at the commencement of December something like one-half the blast furnaces had been blown out, with thousands of workmen out of employment, and although there seemed some hopes of an immediate revival, these were not confirmed by the latest advices at the end of the year; the effect of this state of things on the amount of iron imported from other countries can easily be divined. Thus, from the Customs' House returns, we learn that the importations of iron and steel from Great Britain had fallen off very considerably during the first ten months this year, as compared with the corresponding period of the preceding year. The figures stand as follows:—

	Ten Months Ending October 31, 1872. Tons.	Ten Months Ending October 31, 1873. Tons.	Per cent. less.
Pig iron	175,816	96,395	45 %
Bar, bolt, & rod iron	58,174	22,223	62 „
Iron rails	410,010	160,036	60 „
Hoop, sheet, & plate iron	27,592	17,480	36 „
Tin-plate iron	78,633	76,415	3 „
Steel	19,516	16,594	15 „

From the statistical report of the Secretary of the American Iron and Steel Association we learn that the production of pig iron in the United States in the year 1872 was 2,830,070 net tons, or 2,526,848 gross tons. This quantity was produced in twenty-one States. The ascertained production during the first six months of 1873 was 1,393,075 net tons, and the estimated production for the whole of the year 1873 is 2,695,434 net tons, or 2,406,637 gross tons. The number of States which made pig iron this year was twenty-two—Maine having re-entered the list after a long rest. The excess of production in 1872 over the estimated production of 1873 is 134,636 net tons. If the financial crisis had not occurred, the production of 1873 would have exceeded 3,000,000 net tons. The estimated annual capacity of all the furnaces in the United States is 4,371,277 net tons.

The total number of furnaces in the United States, exclusive of abandoned and projected furnaces, is 636. The total number of new furnaces finished and put in blast in 1872 was forty-one; finished and put in blast in 1873, forty-two; total number of new furnaces put in blast in the last two years, eighty-three. Many of these are among the largest in the country. By the erection of these eighty-three furnaces, the furnace capacity of the country has been increased fully one-fourth; and what is considered as a pretty close estimate of the entire production of rolled and forged iron, in the United States, for the last two years, is given, in net tons of 2,000 lbs. each, as follows:—

	1872.	1873.
Merchant bar and rod	500,000 ...	400,000
Sheet and plate	200,000 ...	250,000
Hoop	30,000 ...	30,000
Nails and spikes	175,000 ...	200,000
Axles, etc.	95,000 ...	100,000
Total net tons	1,000,000 ...	980,000
Add iron and steel rails ...	941,992 ...	850,000
Total rolled iron, net tons ...	1,941,992 ...	1,830,000

The production of cast steel in the United States is estimated as likely to be about 28,000 tons, or some 4,000 tons less than the quantity returned for 1872; on the other hand it is expected that the production of Bessemer steel will amount to 140,000 tons against 110,500 tons last year; about 85 per cent. of the Bessemer steel made in the United States is rolled into rails. The total quantity of pig iron converted into Bessemer steel during the first nine months of this year was 127,384 tons, which was more than the quantity converted in the entire year 1872, that being 125,361 tons. The production of steel by the Siemens-Martin process is only a few thousand tons annually, and is confined to seven establishments; one new establishment was inaugurated this year, but it does not appear that steel can be manufactured as cheaply in the States by this system as by the Bessemer process.

The Bessemer steel works at present in operation can turn out annually 170,000 tons of rails, and are situated at Troy, in New York; Johnstown, Harrisburg, and Bethlehem, Pennsylvania; Newburg, Ohio; and at Chicago (2) and Joliet, Illinois. When the new plant now being put up at the Pennsylvania Steel Works, at Harrisburg, which will double their present capacity, and the Edgar Thomson Steel Works, near Pittsburgh, are completed, the total capacity of the Bessemer works in the United States may, in 1874, be estimated at about 222,000 tons of steel rails per annum.

For the manufacture of pig iron for conversion into steel by the Bessemer process, it has been found advantageous to import rich iron ores from Algeria by the firms of Cooper, Hewitt and Co. and the Bethlehem Iron Company; for the same purpose a trial cargo of iron ore from Bilbao, containing fifty-three per cent. metallic iron, has also been received by the Pennsylvania Steel Company, and is reported as of excellent quality.

The following figures show a summary, in net tons, of the ascertained and estimated production of iron and steel in the United States in 1872 and 1873:—

	1872.	1873.
Iron and steel rails	941,992	850,000
Other rolled and hammered iron	1,000,000	980,000
Forges and bloomeries... ...	58,000	50,000
Cast steel	32,000	28,000
Bessemer steel	110,500	140,000
Siemens-Martin steel	3,000	3,500
Pig iron...	2,830,070	2,695,434

A very elaborate tabular statement, showing the names of all the blast furnaces at present existing in the United States, with their localities, names of proprietors, height, diameter at boshes, character of top and of the blast, do. of the fuel and ores, capacity in make of pig iron per week and actual make in 1872, has been drawn up by Mr. Jos. D. Weeks, the editor of the *American Manufacturer*, and published in the number of that periodical for November 13, 1873, to which we must refer for details, contenting ourselves, in

the present instance, with giving a tabular summary of its contents as follows:—

STATES.	CHARCOAL. Hot Blast. No. Fur.	CHARCOAL. Hot Blast. Make.	CHARCOAL. Cold Blast. No. Fur.	CHARCOAL. Cold Blast. Make.	CHARCOAL. Total. No. Fur.	CHARCOAL. Total. Make.	COKE and COAL. No. Fur.	COKE and COAL. Make.	ANTHRACITE. No. Fur.	ANTHRACITE. Make.	TOTAL. No. Fur.	TOTAL. Make. Tons.
Alabama	14	7,968½	3	2,415¾	17	10,384¼	—	—	—	—	17	10,384¼
Connecticut	6	18,186	3	8,064	9	26,250	—	—	—	—	9	26,250
Georgia	3	2,240	12	2,676	15	4,916	—	—	—	—	15	4,916
Illinois	—	—	—	—	—	—	9	61,098¼	—	—	9	61,098¼
Indiana	—	—	—	—	—	—	8	41,814½	—	—	8	41,814½
Kentucky	19	32,378¾	4	2,240	23	34,618¾	6	41,977	—	—	29	76,595¾
Maine	1	—	—	—	1	—	—	—	—	—	1	—
Maryland	13	25,530	2	1,104	15	26,634	8	12,210¾	6	22,615	29	61,459¾
Massachusetts	5	8,114½	—	—	5	8,114½	—	—	1	1,892¾	6	10,007¼
Michigan	32	80,617	—	—	32	80,617	5	8,889½	—	—	37	89,506½
Minnesota	1	—	—	—	1	—	—	—	—	—	1	—
Missouri	8	54,365¼	1	4,198	9	58,563¼	10	65,150¼	—	—	19	123,713½
New Jersey	1	—	—	—	1	—	—	—	15	97,660	16	97,660
New York	15	8,391	2	2,000	17	10,391	—	—	45	256,754¾	62	267,145¾
North Carolina	3	—	5	764½	8	764½	2	—	—	—	10	764½
Ohio	33	76,828¼	4	8,099	37	84,927¼	62	330,375¼	—	—	99	415,302½
Pennsylvania	7	10,576¾	26	30,568½	33	41,145¼	73	370,709	152	828,367	258	1,240,221¼
Tennessee	14	18,202¼	7	5,394¾	21	23,597	3	4,500	—	—	24	28,097
Vermont	2	2,576	—	—	2	2,576	—	—	—	—	2	2,576
Virginia	17	14,157½	17	9,361	34	23,518½	5	1,581½	1	—	40	25,100
West Virginia	1	950	1	672	2	1,622	5	4,490½	—	—	7	6,112½
Wisconsin	11	36,562½	—	—	11	36,562 7/12	—	—	3	37,247	14	73,809 7/12
Totals	206	397,644¼	87	77,557½	293	475,201⅝	196	942,796½	223	1,244,536½	712	2,662,534⅝

Pennsylvania still maintains her position at the head of the iron-making States. In both 1872 and 1873 her furnaces have produced very nearly one-half of the entire make of the whole country. Previous to the financial crisis many new furnaces were in course of erection; the one at Scranton, belonging to the

Lackawanna Iron and Coal Company, just finished, is sixty-seven feet high with twenty-three feet diameter at the boshes; another new furnace at New Lebanon, erected by Mr. G. Dawson, thirty-five feet high by sixteen feet at the boshes, was blown in in the month of September; the Steward Iron Company's furnace, at Sharon, is also completed, and the Baldwin furnace, at Harrisburg, pertaining to the Pennsylvania Steel Company, fourteen feet at the boshes, was put in blast in November, for producing Bessemer pig iron.

Of the new furnaces at Pittsburgh, four stacks, completed in 1872, deserve special mention because of their large size and great capacity. The Lucy furnace, of Klomand and Carnegie Brothers, is seventy-five feet high by twenty feet diameter of bosh. Its capacity is five hundred and seventy-five tons a week. The two Isabella furnaces are both seventy-five feet high, while the diameter of the bosh of one is eighteen feet and of the other twenty feet. Their united capacity is nine hundred tons a week. They are owned by the Isabella Furnace Company. The Soho furnace, Moorhead, McCleane and Co., proprietors, near Pittsburgh, is sixty-five feet high by eighteen feet bosh. Its capacity is about five hundred tons a week.

Since the crisis, the National Iron Company, at Danville, had failed, and in November, the Lackawanna Iron Company announced to their employés and workmen that they could not continue cash payments. In Pittsburgh, a blast furnace erection company has been incorporated, and an iron ore company formed, in October, at Doylestown, to develop new deposits of iron ore in Bucks county. An English company, to be called the Pennsylvania Iron and Coal Company, is reported to be in course of formation, for the purpose of acquiring and working very extensive coal and iron mines situated in Bedford county, Pennsylvania.

From New Jersey, we learn that the inhabitants of Hackettstown have subscribed £5,000 towards erecting a blast furnace there, and that the new furnace of the Franklin Iron Company, in Sussex county, is completed, and is sixty-seven feet in height, with a diameter of twenty-three feet at the boshes.

A paper has been published by Mr. M. F. Maury, F.G.S., "On the Resources of the Upper Kanawha Coalfields, with a sketch of the Iron Belt of Virginia," which directs attention to these great

deposits, which undoubtedly must soon play a prominent part in the iron manufacture of the United States. At Fisherville, veins of hematite ore are reported to have been discovered, which contain above 50 per cent. metallic iron, and are free from sulphur or phosphorus. The red fossiliferous ironstones of Western Virginia and Eastern Tennessee, which afford some 60 per cent. iron when smelted, are being gradually opened up, but not by any means as yet to the extent which the capabilities of this coal and ironstone deposit warrants. In order to show the expense of making iron in this district, a correspondent sends the following statement of the actual results of the operations at the Roane Iron Company's Works, in East Tennessee, for the month ending Saturday, December 26th, 1872:—

Materials and Wages.	Quantity in lbs.	Dols.	Cents.
Ore charged into furnace ...	2,144,000 ...	2,835	86
Cokes do. ...	891,200 ...	2,005	20
Limestone do. ...	1,339,200 ...	1,101	80
Limestone do. ...	552,700 ...	304	58
Labour	— ...	1,170	15
Salaries	— ...	400	00
Materials for store	— ...	303	37
Blacksmiths' work	— ...	118	56
Foundry castings	— ...	98	03
	Total ...	8,337	55

Product, 590 tons No. 1 mill iron, costing 14·13 currency dollars per ton, the ore yielding 62·4 per cent. iron.

In English money the above figures represent per ton of pig iron made: Iron ore, 15s. 6d.; fuel, 17s.; limestone, 1s. 9d.; wages, stores, &c., 12s. 6d.; total, £2 6s. 9d., which, at the selling price of £6 16s. 0d. per ton, shows a profit of £4 9s. 3d. per ton.

From Ohio, it is announced that seven blast furnaces are in course of erection at Jackson, and that the Ironton Steel and Iron Company have acquired the Ironton Mill, and are building a blast furnace of a capacity of 50 tons pig iron per day. The Akrom Iron Company's blast furnace commenced operations in October, and in the summer a company, called the Valley Iron Company, of Cleveland, had been formed, with a capital of £20,000 in shares of £20 each. At the Joliet Bessemer Steel Works, in Illinois, 3,100

tons of this description of steel were made in the month of September, 1873; at Chicago, the Nes Silicon Steel Company are building new works, in addition to their previous works at Elmira and Rome, New York, and at Sandusky, in Ohio. From Utah, we hear that a company, with a capital of £200,000, has been formed in Salt Lake city for smelting iron ores in a new description of furnace, invented by a Mr. Stevens there. It may be mentioned that some time back samples of iron ore and coal were received from this district by the author, with a view to the erection of works there, the iron ore was found to be hematite of the richest kind, but the coal was a lignite, peculiar for the large quantity of water which it gave off when heated, notwithstanding that in its natural state it very much resembled dry cannel coal.

New discoveries of magnetic iron ore of the finest quality, and in immense quantity, are reported to have been made on the banks of the Gasconade river, in Missouri.

In Alabama, the Woodstock Iron Works have been put in operation and the Tecumseh Iron Company formed, with a capital of £20,000. Since 1872, attention is being directed to the shipments of iron ores to the Northern States; this year Mr. George H. Hull, of Louisville, Kentucky, has alone shipped some 25,000 tons of Alabama brown hematite to the blast furnaces in Indiana and on the Ohio river.

A blast furnace has this year been in work in Texas, being situated near Jefferson, in Marion county; it is expected that the Texas and Pacific Railway, of which over two hundred miles are now in operation, will open up rich deposits of iron ore and coal in Texas.

The steel works of Messrs. Thompson and Paxton, at Cumberland, in Maryland, are just completed, and the American Steel Company have acquired the works of Schneller and Hotchkiss, in Connecticut. It is announced from New York that at the Elmira Steel Works, by aid of a new flux, old Bessemer steel rails are being re-rolled with success.

Extensive deposits of calcareous iron ore, containing between 40 and 50 per cent. of metallic iron, and supposed to be of superior quality for the production of Bessemer pig iron, are reported to have been discovered in Clark county, Indiana, within 20 miles of Louisville. The Terre Haute Iron Works were, in the month of

September, destroyed by fire, the loss, of which only about £7,400 was insured, being estimated at fully £35,000.

From Michigan, it appears that up to the 5th November, 1873, at which date the shipments for the season had about closed, 1,099,033 tons of iron ore and pig iron had been shipped from the Lake Superior district, against a total shipment in 1872 of 1,015,250; it was expected that the increase would have been much larger this year, and the reason given for its not having been so is the cancelling of orders due to the financial crisis. The new charcoal blast furnace at Elk Rapids, near Marquette, which has been constructed for smelting Lake Superior ores, has a capacity of twenty-five tons pig iron per day; another new furnace at Menominee, which employs charcoal made from the slabs and edgings of the saw mills there, is now making 130 tons pig iron per week, with a consumption of 185 bushels of charcoal to the ton of iron. With respect to the Lake Superior iron region, we would direct attention to the excellent memoirs of Major T. B. Brooks, in charge of that department of the Michigan Geological Survey. We have received those entitled Historical Sketch of the Discovery and Development; Lithology or Mineral Composition and Classification of the Rocks; Method and Cost of Mining Specular and Magnetic Ores; and on the Chemical Composition of the Ores, which are published as separate pamphlets, by Julius Bien, New York, 1873, and can recommend them as containing a large amount of information concerning this very interesting district.

Mr. G. F. Wilson, of the Rumford Chemical Works, has made some excellent steel from the Rhode Island iron ores, and proposes to erect furnaces for extending the manufacture. Although the Cumberland Iron Mountain, which is nearly the highest land in this State, is reported to be one vast mass of iron ore, which has been worked off and on since 1755, and Rhode Island itself is said to possess more iron ore in proportion to her population than any other State in the Union, it is strange to observe that hitherto the production of iron has been quite nominal in quantity.

It is somewhat remarkable that there is at present no iron furnace in Delaware, although forty years back there were many charcoal furnaces in Sussex county, which produced iron of the best quality, and there are known to be deposits of excellent iron ore.

Some excitement was occasioned amongst the American iron-masters by the announcement being made that American-made iron was being exported from the United States to Great Britain; it gave rise to a newspaper discussion, which, however, resulted in proving not only that no such shipments had ever taken place, but that at the prices ruling in America they could not be carried out except at a great loss. We do not think that the British iron-master has anything to fear from such competition for many years to come, although there can be no doubt that ultimately, the great natural resources for iron-making in the United States cannot but have a very marked influence upon the European iron market. In the Exhibition of Vienna, the iron manufacturers of the United States were but very poorly represented, the principal object which attracted attention being a model of Seller's rotary puddling furnace, which appears to be but a modification of those on the Danks's system, and has been previously alluded to in these reports.

Amongst the late publications in America we observe the following:—

Overman, "Manufacture of Steel," new edition, with Account of Recent Improvements in Steel, by A. Fesquet, 12mo., cloth, pp. 285, Philadelphia.

Overman, "Treatise on Metallurgy," 6th edition, royal 8vo., pp. 724, with 377 woodcuts. New York.

B. METALLURGICAL TECHNOLOGY.

Magnetism of Iron and Steel.—A paper "On the Magnetic Permeability and the Magnetism of Iron, Steel, and Nickel," is published in the American Journal of Science and Arts for December, 1873, and in Comptes Rendus de l'Academie des Sciences for July 14, 1873, some notes on Magnetism, by M. Du Moncel, will be found. In this same number will also be found a communication, by M. Jamin, "On Modifications of the Magnetic Power of Steel by Tempering and Annealing," from which it would appear that soft iron takes the greatest temporary magnetism, whilst tempered steel receives much less, and the less in proportion as it is harder. A bar of cast steel, annealed at a red heat, showed a force of 1,290 grammes, with a current of twelve elements which, the same bar hardened, indicated only 75 grammes under the same conditions. Steel of good quality when very hard and in thin plates is declared to

be altogether unfit for permanent magnets; inferior steel retains its polarity, and may be made into powerful magnets after full hardening and without annealing.

Spectrum of Iron.—In the Comptes Rendus de l'Academie for 21st July, 1873, P. Secchi states as the results of careful experiments, that he could not obtain the line K 1,474, which is asserted to belong to iron, even by the employment of 50 Bunsen's couples, and after examining various descriptions of iron; he, therefore, concludes that if it really belongs to iron, which he is inclined to doubt, it is only developed under circumstances of temperature as yet unknown.

Molecular Changes in Iron. — Professor Thurston has published, in the *Iron Age* an elaborate paper "On the Molecular changes brought about in Iron by changes in temperature," a subject of great importance to engineers. Several of the conclusions arrived at by Professor Thurston, such as his opinion that at temperatures below 72 degs. Fahrenheit the tenacity of iron increases with the diminishing temperature, at the rate of about 0·02 to 0·03 per cent. for each degree, do not agree with those of other observers.

Burnt Iron.—In our second report for 1872 we alluded to the experimental researches of M. Carron, on crystallized or burnt iron, in continuation of which we may now mention that this gentleman, in a communication to the Academy of Sciences in Paris, on the 20th November, 1873, recommends that so-called "burnt" iron, *i.e.*, such as has become crystalline and brittle from imperfect forging, should be heated to bright redness and then plunged into a boiling solution of sea salt, in which it is allowed to remain until both the iron and solution are of about the same temperature; during this operation the iron when plunged into the salt water becomes instantly covered with a white coating of salt, which, as it were, isolates it from the fluid and much retards its cooling. This treatment is particularly recommended for treating finished forgings, as, even if not required, it can do them no harm, whilst if they, on the contrary, may have been exposed to a too great or too prolonged a heat, the process as already described will correct the faults.

Pyrometer.—In Les Mondes, vol. 31, No. 13, M. J. Salleron describes a modification of a pyrometer, long in use in a somewhat different form. Its principle consists in calculating the temperature

of furnaces, hot blast, &c., from the difference in temperature of a quantity of water before and after a copper or platinum cylinder, which has been exposed to the heat, has been immersed in it. The water is contained in a cylindrical vessel of sheet copper, open at its upper end, and surrounded by another of brass, in which the former is supported by an annular disc of wood, so that a layer of air is retained between the vessels in order to diminish the amount of heat lost by radiation and conduction. The mouth of the vessel is closed by a wooden cover, having an orifice through which a determined weight of water and also the copper or platinum cylinder, when hot, can be introduced. The cylinder, which, when of copper, weighs 106 grammes, rests upon an arm passing through the wooden cover, which is so constructed as to enable it to be agitated in the water, so that it may become uniformly heated, when its temperature is determined by a thermometer. When the apparatus is used, half a litre of water is measured into the vessel and its initial temperature (t) determined by a thermometer. The cylinder of copper, weighing 106 grammes, after having been brought to the heat of the furnace, of which the temperature (T) is desired to be ascertained, is now quickly immersed in the water and agitated until the mercury in the thermometer, which first rises quickly, then more slowly, and finally remains stationary for a few moments, when it is recorded (t^1), before beginning to fall; the temperature of the furnace will now be found by the simple formula, $T = 50 (t^1 - t) + t$. The accuracy of this method depends upon the instantaneous immersion of the heated copper cylinder in the water, so that no loss of heat shall take place during its passage from the furnace to the vessel containing the water, for which purpose M. Salleron places the copper cylinder in an iron tube, with a wooden handle at one end, so constructed that, after heating the whole in the furnace, it can easily be carried to the calorimeter and the cylinder, by half a turn of the tube, at once immersed in the water; the heat of the exterior iron tube having prevented any loss of heat in the operation. An elaborate enquiry into the different systems of measuring high temperatures has been this year published, by Prof. Weinhold, in the Programm der Koeniglichen Hoehern Gewerbschule zu Chemnitz, Ostern, 1873, which is well worthy of study.

Blast Furnaces.—A long and important paper on Blast Furnaces, with illustrations, has been published by M. L. Gruner,

Inspector-General of Mines, in the Bulletin de la Société d'Encouragement pour l'Industrie Nationale, No. 249, September, 1873.

From the New York Engineering and Mining Journal for December 23rd, 1873, we extract the following description of the new furnace of the Cedar Point Iron Company, Port Henry, New York, which is held forth as a model of an American furnace, up to date in all improvements, and intended for smelting the magnetic iron ores of the Lake Champlain district with anthracite coal. Its make is estimated at 280 tons per week, and although a comparatively small furnace, its construction is stated to be 90,000 dols., or more than that of the largest furnace in the United States. It was designed and built under the superintendence of Mr. Thomas F. Witherbee, from whom the following details were obtained :—

Stack—Iron shell 27 feet in diameter by 58 feet high, resting on six cast iron columns, each 12 feet long, making total height of stack 70 feet. Boshes—16 feet diameter; angle 71°. Diameter of stack at top under bell and hopper, 13½ feet. Elevator consists of one pneumatic hoist, 36-inch cylinder, built by Delameter Iron Works, New York. Platform of hoist capable of lifting four barrows at a time, and a weight of 3½ tons if required. In addition to blast from main engine, the hoist is furnished with a Knowles direct-acting air-pump, 14-inch steam, 30-inch blowing cylinder by 36-inch stroke, to be used when main engine is not running, and also during extremely cold weather, when the pneumatic cylinder might possibly freeze up, if using air from main engine containing more or less moisture. Air-pump to be located where it will find cold and consequently dry air.

Casting-house—60 feet by 69 feet, of bricks; galvanized iron roof; walls 21 feet high.

Scale-house—26 feet by 26 feet inside; iron roof.

Hot Blast—Four Whitwell fire-brick stoves, 22 feet diameter by 29½ feet high; heating furnace of each stove 11,500 square feet.

Top-house—Built by Delamater, New York; iron, supported by the cylinder of pneumatic hoist.

Bell and hopper—Diameter of bell 7½ feet, worked by an air-cylinder 26 inches in diameter.

Engine hoist—60 feet by 66 feet, of bricks; height from basement to eaves, 48 feet. In basement are located one Knowles pump, 10-inch steam, and 5-inch water-cylinders, by 12-inch

stroke; one Knowles pump, 10-inch steam, and 6-inch water-cylinders, by 18-inch stroke, to feed the boilers. The latter pump is a mining pump, having a plunger working into two single-acting pumps, instead of a piston in one water-cylinder. In basement are also placed two Knowles pumps for pumping water into a tank for general furnace use. Steam cylinders are 24 inches diameter; water cylinders, 16 inches; stroke, 24 inches.

Blowing engine—Built by Henry G. Morris, Philadelphia. Steam cylinder, 16 inches diameter by 8 feet stroke; blowing cylinder, 100 inches diameter by 8 feet stroke. The engine is known as a side-lever engine. Weight of some of the principal parts of engine: Levers, each 11 tons; blowing cylinder, $9\frac{1}{2}$ tons; fly wheels, 22 tons each; steam cylinder, $7\frac{1}{2}$ tons; cross-heads of Bessemer steel, $2\frac{1}{4}$ tons each (the largest steel forgings ever made in this country); diameter main shaft, 18 inches; diameter beam centre, 18 inches; total weight of engine, 180 gross tons.

Boilers—Built by Thomas S. Sutherland, Franklin Iron Works, Troy, N.Y., who also furnish all the wrought-iron work for stack, stoves, steam pipes, water-tank, chimneys, &c. Number of boilers, 8, set two and two, each two connected by mud-drains of same diameter of boilers, and $10\frac{1}{2}$ feet long. Diameters of boilers—55 feet long by 5 feet diameter; shell, $\frac{3}{8}$ inch thick; heads, $\frac{1}{2}$ inch thick; iron, Bay State, "C," 1 inch.

Boiler Chimney—Of wrought iron, 8 feet $7\frac{1}{2}$ inches at bottom, 6 feet at top, and 114 feet 9 inches high, built with fire-bricks.

Hot blast chimney—Same as boiler chimney.

Peat as Fuel in Blast Furnaces.—The experiments made in the Lake Superior district, in using peat in the blast-furnaces for iron smelting, were briefly alluded to in our third report for 1872; we now extract from the Marquette Mining Journal of October 11th, 1873, the following additional information on this subject. The peat blast-furnace, after having been enlarged so as to be 9 feet internal diameter at the boshes, and increased in height to 48 feet, as well as provided with additional boiler capacity and an improved hot blast stove, was put into blast on the 1st of November, and is working extremely well. The charcoal used along with the peat, is made from soft wood only, weighing from 14 to 17 lbs. per bushel; the lighter sort being such as is charred in pits, whilst the charcoal made in ovens or kilns is heavier. The blast-furnace,

when filled in the first instance with charcoal, did not, even for some time, furnish sufficient gas for supplying the boilers or hot-air apparatus, which, however, was immediately the case after peat in small quantities had been added to the charge. The peat is prepared by passing through a large cylinder, in which it is cut to pieces by rotating cutters, after which it is spread out upon platforms and air-dried, when it weighs 40 lbs. to the bushel. The charge of fuel consists of 400 lbs. charcoal to 120 lbs. of peat, with a blast-pressure of three-quarters of a pound to the inch, and at present the make of pig iron is from eight to ten tons per day. The ore employed is of the best quality from the Lake Superior district, in the proportions of one-quarter hematite to three-quarters specular oxide of iron. So far, the pig iron produced is of superior quality, and the furnace, besides increasing gradually in yield, is working so uniformly and promising, that the success of the peat is now regarded as beyond question. It is intended to increase gradually the amount of peat in the charge as the furnace works its way forward towards its estimated capacity of twenty tons per day, until the amount used will be equal in bulk to that of the charcoal ; and it is believed that it will not only prove the stronger fuel of the two, but also, that it will carry the burden of the furnace equally well with the charcoal. Some 350,000 bushels of the prepared peat is now ready for use at the furnace, and an inexhaustible quantity can be obtained at but a very small expense, so that these experiments bid fair to be only the first steps towards the erection of large ironworks on the spot for the employment of this fuel, especially as its adaptability to puddling and heating furnaces worked by gas has already been fully demonstrated.

Influence of Titanium in Iron Smelting.—As it is well known that cast irons made from most ores containing titanic acid, do not themselves contain any or only a trace of titanium, the precise reason why this substance should have that beneficial influence on the quality of the iron or steel made from such ores, which is generally ascribed to it, is somewhat difficult to explain. In the Jern-Kontorets Annaler, it is stated that it is common in Sweden, when the iron ores are sulphury, to add to the charge titanic iron ores (containing less than 10 per cent. titanium), which, it is asserted, prevent the iron produced becoming red short, possibly, it is imagined, owing to the formation of compound of

sulphocyanogen with titanium; as yet, however there is no evidence to prove that titanium has the same influence on the smelting of ores containing phosphorus.

Composition of Blast Furnace Slag.—An analysis of an iron slag of a fine blue colour, produced at the Barrow Works, in Lancashire, has been made by Mr. McD. Irby, in the laboratory of the University of Virginia. Its specific gravity was found to be 2·85, and as the powder when treated with hydrochloric acid emitted fumes of sulphuretted hydrogen, as well as the examination proving that none of the sulphur contained in the slag was present in an oxidised form, it seems most probable that the blue colour was due to sulphur, in a state of combination analogous to ultramarine or lapis lazuli. The percentage composition is given as follows:—

Silica	46·683
Alumina	5·769
Protoxide of iron	1·208
„ „ manganese	1·062
Lime	39·168
Magnesia	0·987
Soda	1·276
Potash	0·967
Sulphur	2·074
	99·194

Utilization of Blast-Furnace Slag.—In connection with this subject, which is now attracting much attention here in England, we would allude to the extremely simple method for disintegrating the slag into the form of sand, employed at the Sclessin Iron Works, near Liége, which was shown to the members of the Iron and Steel Institute, on the occasion of the late meeting in Belgium. No machinery whatever is employed in the operation, which is merely effected by so placing a small water pipe below the slag run off the blast-furnace, that the molten slag, as it pours down, is met by the rush of water from behind, and at once broken up into the condition of a coarse sand, which falls into a sump in front, from which it is lifted up by ordinary chain buckets and loaded directly into the railway wagons. Considering the complicated machinery which has been devised in this country for effecting the same object, it is

quite refreshing to see how perfectly this simple and cheap process does its work.

In the Vienna Exhibition, samples of the so-called slag wool, and its application to coating steam-pipes, boilers, &c., as a non-conducting cover, were shown, and appeared excellent in its way. It is formed by blowing steam against or through the liquid slag as it issues from the blast-furnace, and has very much the appearance and texture of dirty coarse sheep's wool.

Action of Slag on Fire-Clay.—The results of an experimental enquiry into the behaviour of different fire-clays when in contact with iron blast-furnace slag at high temperatures, has been published in Dingler's Polytek. Journal, cciii., p. 445–450, by Carl Bischof. The experiments were made by mixing the fire-clays with the desired proportion of powdered slag, and moulding it into a small cylinder which is exposed to the heat until it loses shape. With Hessian fire-clay, 1 per cent. of slag is sufficient when the temperature is as high as the fusing point of platinum. Gruenstadt, Muelheim, and Belgian fire-clays required from 5 to 7 per cent.; Laaren No. 2 fire-clay, 6 per cent.; Garnkirk, 8 per cent.; Laaren No. 1, 13 per cent.; and Zellitz fire-clay, 14 per cent. Of course, these results are merely comparative, since blast-furnace slags vary greatly in chemical composition; and in trials made with two different slags, one produced along with grey Bessemer pig iron, which contained 54 per cent. of lime, and the other from white iron, with 41 per cent. of lime; the latter exhibited less tendency to make the fire-clay fusible.

Phosphorus in Coal.—In Dingler's Polytek. Journal, 208 p. 64, Durand-Claye directs attention to the presence of phosphoric acid in most coals often in sufficient quantity to affect the quality of the iron made with it, more especially for making Bessemer steel. A coal which contains 8 per cent. ash and yields 65 per cent. coke, will, if the ash contains, as is frequently the case, 1½ per cent. phosphoric acid, and 26 cwt. of coke is used for reducing the ton of cast iron, cause some 2½ lbs. of phosphorus to combine with the iron ore, or more than 0·001 per cent. phosphorus from this source, independent of what may be reduced for the ore.

Desulphurising Coke.—In Dingler's Polytekn. Journ., ccviii., p. 463, Dr. Hofman recommends that in extinguishing the coke it should be drenched with the waste liquor from the chlorine stills,

which is an impure acid chloride of manganese, and has the effect of driving off the sulphur in the coke in the gaseous form, as sulphuretted hydrogen. As, however, this effect is in reality only due to the free hydrochloric acid present in the liquor, it might be found quite as economical to use the weak muriatic acid from the condensing towers, especially when this is a waste product, as is still the case in some chemical works. It is stated that in one of the large Rhenish ironworks a solution of the chlorides of manganese and calcium has also been employed for this purpose.

Blowing Machines.—In the Chronique de l'Industrie, vol. II., p. 27, September, 1873, will be found a description with drawings of the large vertical blowing machine sent by the Seraing Company to the Vienna Exhibition. We must refer to the paper itself for details, but it may be mentioned that this machine when going at its normal rate of 12½ strokes per minute, with a pressure of blast of 7¾ inches of mercury, develops an effective force of 230 horse-power. We find that a description and drawing of this engine is also given in *Engineering*, for October 10, 1873.

Production of highly Silicised Pig Iron.—Since our last report, in which we gave an account of Professor Jordan's researches on this subject, a paper entitled "Researches on cast irons rich in silicon," has appeared in the Annales des Mines, for 1873, pt. 4. p. 1, written by M.M. L. Troost et P. Hautefeuille, in which the authors give the results of their investigations into the behaviour of compound of iron with silicon under various circumstances, showing that the reducing action of the carburet of iron on silica is a very slow one, and that it is interfered with by basic slags, their experiments having proved directly that when a silicious cast iron is melted with lime or with a very basic silicate of lime, silicon is removed from it. They also consider that one of the causes of the formation of cast iron containing much silicon is the presence of alkaline silicates in the furnace, and state that a mixture of carbonate of potash, charcoal, iron filings, and silica, when melted in a blast furnace at a high temperature, will at once afford a cast iron containing as much as from 15 to 16 per cent. of silicon, along with 2·94 per cent. carbon, a result which they consider due to the reduction of potassium, which, by re-acting in its turn on the silica, sets the silicon at liberty to combine with the iron.

Gases in Molten Cast Iron.—M. A. Ledebur, of Groeditz, in Saxony, has published in the Berg und Huettenmænnische Zeitung, for October 24, 1873, a paper "On the Emission of Gases from Molten Cast Iron," and, according to him, this is due to one or more of three causes, which are:—

1. The escape of gases, which have been taken up by the metal in the process of smelting, and which in the act of the metal being tapped or poured into moulds, again assume the gaseous form either from diminished pressure, or from the sudden motion of the metal, or owing to its solidification.

2. The formation of gaseous compounds, in consequence of the molten metal coming into contact with the external air.

3. Or the formation of gases brought about by chemical action when the molten metal comes in contact with the sides of the moulds.

The paper itself is too long to be more than referred to here, but in connection with the subject we would also direct attention to the experimental researches of M.M. L. Troost and P. Hautefeuille, published in the Comptes Rendus de l'Academie de Sciences, vol. xxvi., p. 482, a translation of which will be found in the Journal of the Chemical Society for July, 1873, vol. xi., p. 729.

Purification of Cast Iron.—M. Tessie du Motay, the well-known French inventor, who is, perhaps, better known for the number and extraordinary range of the subjects of his inventions, than for their successful application in practice, has, this last summer, brought forward a new process for the manufacture of pure iron, from such pig iron as from its contents in sulphur, phosphorus, arsenic, or silicon, separately or in combination, cannot be converted into malleable steel, either by the Bessemer, gas-reverbatory, or other process. The main points of the new invention are described by him as follows: (1) an apparatus, called an aerodynamic purifier, which allows, owing to their difference in density, certain fusible chemical compounds to pass through the molten cast iron, which can unite with the metalloids rendering it impure, so long as the action of the air or oxygen continues to decarburate the cast iron; the products being pure iron, steel, or purified cast iron, according as the decarburation is more or less complete; (2) a system of preparing the cast iron to be treated in such apparatus, which ensures the refining being carried on without

the iron ceasing to be liquid, until the whole of the carbon present in it is completely removed; (3) the preparation of a special flux, containing chemical purifying agents of less density and greater fusibility than cast iron, having for its main object the fusion of the lime contained in the fluoride of calcium, and in the oxides of iron and manganese, this base possessing beyond all others, the property of fixing in the presence of fluoride of calcium, sulphur, phosphorus, and arsenic, as long as the action of the air or oxygen is kept up. (4) The employment of spiegeleisen or ferromanganese by successive additions, to complete the action of the above flux during the passage of the air by which the iron is being decarbonised; (5) the novel employment of the peculiar property possessed by pure ferro-manganese, or its alloy with tungsten and titanium, to render steel or iron malleable, although still retaining a certain amount of sulphur, phosphorus, or arsenic, after having been more or less completely decarbonised in the apparatus or gas-reverberatory furnace; and, (6) finally, a process for making steel from cast iron, containing phosphorus, sulphur, arsenic, or silicon, in excess, without previous preparation, by converting it in the above or any similar apparatus, with the assistance of chemical purifying agents.

Another process for the purification of iron has, according to the Journal of the Franklin Institute, been patented in the United States, by a Mr. Thomas Shaw, which consists in directing a jet of dry steam upon the molten cast iron as it issues from a cupola furnace. The floor of the house being divided into four compartments, it is asserted that the metal falling farthest from the nozzle is found to be soft wrought iron; that in the next compartment, cast steel; in the next refined cast iron; and in the nearest of all, ordinary cast iron. We would merely remark, that in the case of both this and the preceding process, we have not had the opportunities for verifying the statements by personal inspection, so have to give the descriptions almost in the words of the authors.

Re-melting Pig Iron.—In our report, No. 3 for 1872, we noticed a form of cupola with reservoir for the melted metal on one side of it, which was brought forward by M. Henry Krigar, of Berlin, as a novelty, and highly thought of on the Continent, especially for melting iron for the Bessemer converters. We now find that a similar arrange-

ment was long before patented in the United States by a Mr. McFarland, and one was put up as far back as 1859, at the Broadway Foundry, in St. Luis, a plan and section of which has been reproduced in the number of *Engineering* for December 5th, 1873, to which we would refer for details. A cupola with reservoir attached, which is known by the name of Swain's patent cupola and receiver, is made by Mr. Ellis, of Salford, and has been patented in England, Belgium, Austria, and the United States, it seems to be but a revival of the above older invention. The advantages claimed for these cupolas are that:—1. The iron is melted quicker and in larger quantities than on the old system. 2. The iron is rendered hotter, is more thoroughly mixed, and makes better castings. 3. Time is saved and overtime avoided by the use of the reservoir. 4. Castings of large and small size can be made with equal ease. 5. A considerable saving in fuel is effected, as the blast does not pass entirely through it as in the ordinary cupola. 6. The iron may be kept in reserve and hot for a considerable time.

In the Chronique de l'Industrie for Dec. 24, 1873, a communication from A. Ledebur, of Groeditz, in Saxony, takes into consideration the best form of cupola to be used when very large quantities of iron have to be melted at a time for the purpose of making extra large castings, such as the great anvil blocks for heavy steam hammers, &c. In the paper he gives the details of the cupola employed when founding an anvil for the Riesa Works, which weighed some 80 tons, in which case, after a careful consideration of the subject, he constructed his cupola of a rectangular section, with the angles rounded off as in the Rachette furnaces, having two rows of tuyeres placed horizontally one above the other on the long sides of the furnace, and a front reservoir (like in the Krigar cupola) which could contain some 15 tons of molten iron. The result was extremely satisfactory, and although the pressure of blast was only from 0·4 to 0·6 inches of water, this cupola supplied with ease seven tons of molten iron per hour.

Alloys of Iron.—A new process for the manufacture of alloys of iron with manganese, tungsten, titanium, or with silicon, has recently been brought forward by La Compagnie des fonderies et forges de Terre-Noir, La Voulte et Bességes, which will be found

described, with drawings of the special blast furnace used, in the Chronique d l'Industrie, 1873, vol. II., p. 235.

This system consists in mixing cast or wrought iron or steel previously brought to a fine state of division such as filings, turnings, pulverised iron sponge, or granulated iron with ores of manganese, tungsten, or titanium separately or together, or with quartz also, in a state of fine division, and in such proportion as will furnish the desired alloy. When this mixture is moistened throughout with an ammoniacal solution or with slightly acid water, and compressed into balls by the hand or in an iron mould, heat is developed, and after some hours when the mould is opened, it will be found to have aggregated to a compact and hard mass, requiring blows of a hammer to break it into fragments, which will stand a red heat and not begin to break up until almost at their point of fusion. By treating these blocks or fragments in a suitable furnace at a very high temperature, alloys of iron, containing from 25 up to 75 per cent. manganese, silicides of iron, containing up to 22 per cent. silicon or alloys of iron with tungsten and titanium, or triple alloys of these different metals, may be obtained. The furnace employed is a small cupola, the shaft of which is made of the best firebricks, and rests upon a cast-iron bearing ring, supported by four pillars, so that the whole of the lower part of the furnace may be removed when required for repairs; between the lowest part of the shaft, which is conical, and the crucible or hearth of fusion, is an intermediate part, also conical, recommended to be made of lime, magnesia or pure alumina, encased in a sheet iron conical casing, supported or hung from the bearing ring previously alluded to, and below this the moveable crucible, which is simply pressed or held up to meet the conical part by means of wedges below it, so as to be easily disconnected for repairs, as it is very strongly attacked during the operation. The crucible itself is formed of lime, magnesia, or also of a solid piece of carbon, made by mixing powdered graphite, gas coke or other pure coke, with tar, and then baking the whole at a low red heat for some hours until it forms a compact hard mass, free from cracks or fissures. At the top of the crucible, a single tuyere lets in the blast, which should be heated at least to 670° Fahrenheit, and have a pressure of some 5 or 6 inches of mercury. A patent, No. 1,574, dated May 1, 1873, by A. Browne, London, being a communication entitled "Furnace for the

Manufacture of Metallic Alloys," appears to embody all the features of the above process.

As a substitute for and as an improvement upon cast steel, M. Levallois, of Paris, has patented in France the employment of three new alloys of iron, with tungsten and nickel, which can be worked like ordinary steel, and are said to be very hard. The three alloys contain the respective metals in the following percentage proportions:—No. 1, soft iron 93 parts, tungsten $6\frac{1}{2}$ parts, and nickel $\frac{1}{2}$ part: No. 2, soft iron 95 parts, tungsten $4\frac{1}{2}$ parts, and nickel $\frac{1}{2}$ part; and No. 3, soft iron 97 parts, tungsten $2\frac{1}{2}$ parts, and nickel $\frac{1}{2}$ part. The crucibles and furnaces employed are similar to those ordinarily used in melting cast steel, but a special flux is made use of, which is composed of 36 parts boracic acid, 32 parts calcined quartz, and 32 parts washed carbonate of lime; all of these substances, after having been powdered and mixed, being melted together in a crucible, poured out upon an iron plate, and the solidified mass broken into small fragments. When making the alloy, the tungsten and nickel are first placed in a tube of soft iron, with about 1 per cent. of the flux, and this tube is placed in the middle of the rest of the iron in the crucible, which is itself covered with from one-half to 2 per cent. of the same flux. When the whole is melted it is poured as usual into moulds of sand or metal.—Chronique de l'Industrie, vol. 2, p. 170, 1873.

Definition of the term Steel.—In the Mémorial du XXV Anniversaire of the Association of Engineers of the School of Arts, Manufactures, and Mines, of Liége, published this autumn at Liége, M. Adolphe Gruner, the head of the steel department of the Société John Cockerill, at Seraing, communicates a note on the "Definition of Steel." This gentleman had previously, in 1869, defined the term steel as including all malleable products of the iron industry, obtained from a state of fusion, in contradistinction to the term iron, which he reserved for all malleable products which have not undergone absolute fusion; although this definition has been accepted by Professor Jordan, and other writers on siderurgy, it clashes somewhat with our old views, to find that under this system, our long-known cementation, or blister steel, must be regarded but as carburetted iron, whilst fused iron, containing none, or but a trace of carbon, must be classified as

steel. The two series of products, *i.e.*, the irons and steels, are classified by M. Gruner as follows:—

Percentage of Carbon.			
0 to 0·15 %	0·15 to 0·45 %	0·45 to 0·55 %	0·55 to 1·50 % or more.
Series of the Irons.			
Ordinary Irons.	Granular Irons.	Steely Irons or Puddled Steels.	Cemented Steels. Styrian Steel.
Series of the Steels.			
Extra soft Steels.	Soft Steels.	Half soft Steels.	Hard Steels.

AUSTRIAN CAST STEELS.—From the Berg und Huettenmænnische Jahrbuch, 3 Heft., xxi. Bd., Wien., 1873, we extract the following analyses of cast steels, made (*a*) by the Neuberg-Mariazeller Company, analysed by M. Lill, and (*b*) by the St. Egidi und Kindberger Iron and Steel Company, analysed by M. Lill and A. Eschka:—

	(*a*)	(*b*)
Carbon	0·638	0·375
Silicon	0·444	0·056
Phosphorus	0·042	0·055
Sulphur	0·009	0·011
Manganese	0·640	0·164
Copper	0·100	0·050
Cobalt	——	0·025
Iron by difference	98·127	99·264
	100·000	100·000

CAST STEEL.—The following mixtures for the preparation of various classes of cast steel have been patented by Mr. T. Brooks, of Minerva, Ohio, U.S.; one of them is 74 lbs. bar iron, 14 ounces tungsten, 8 ounces charcoal, 3 ounces manganese, and 8 ounces fluorspar or chlorophane, the whole being melted down in a crucible as usual. For a finer quality of tool welding steel it is recommended that 2½ ounces of tungstate of calcium be substituted for the tungsten in the above receipt. For making file steel he recommends using 74 lbs. Bessemer scrap, 1½ lb. cast iron; 2 lbs. fluor-spar or chlorophane; ½ ounce manganese; 1½ ounce charcoal, and 1 ounce bismuth.

BESSEMER PROCESS.—According to Dingler's Polytek. Journal, vol. 209, p. 216, Messrs. Rochussen and Daelen's improvements on this system of steel-making consist of putting rich iron ores into the converter along with the molten pig iron, and also in lining the

converter itself with such iron ore previous to the "blow." They assert that not only is the proportion of blast required for the "blow" thereby diminished in the proportion of 8 to 5, but that the quantity of steel obtained is also increased, and mention an instance in which four and a half tons of pig iron, converted along with eight tons of iron ore, containing 60 per cent. of iron, yielded seven and three-quarters tons of Bessemer steel.

The following analyses taken from vol. 21 of the Berg und Huettenmænnische Jahrbuch, Wien, 1873, show the percentage chemical composition of the various products from the blast furnace to the Bessemer converter, as carried out at the Reschitza Iron and Steel Works in Hungary:—

1. Grey Bessemer pig, analyzed by H. Sturm:

Carbon combined	0·730
„ free (graphite)	3·110
Silicon	1·860
Phosphorus	0·106
Sulphur	0·015
Copper	0·050
Cobalt	trace
Manganese	1·200
Iron (by difference)	92·929
	100·000

2. Blast furnace slag, produced along with 1, analysed by M. Lill:

		Oxygen.	
Silica...	46·80	... —	... 24·96
Alumina	6·95	... 3·24	
Protoxide of iron ...	0·18	... 0·04	16·61
„ Manganese	1·50	... 0·34	
„ Copper...	trace	... —	
Lime	41·08	...11·74	
Magnesia	2·90	... 1·16	
Potash with some soda	0·50	... 0·09	
Sulphide of calcium ...	0·24	equivalent to 0·11 % sulphur.	
Phosphate of lime ...	0·057	„ „ 0·011 % Phosph.	
	100·207		

3. Bessemer steel, converted from 1, analysed by A. Eschka:

Carbon	0·133
Silicon	0·072
Phosphorus	0·114
Sulphur	0·010
Manganese	0·145
Copper	0·045
Cobalt	trace
Iron (by difference)	99·481
	100·00

4. Bessemer converter slag, along with 3, analysed by M. Lill:

Silica	59·05
Alumina	4·11
Protoxide of iron	8·80
„ Manganese	26·00
Lime	2·01
Magnesia	0·40
Alkalies	trace
Sulphur	0·030
Phosphoric acid	0·023
	100·423

Spiegeleisen.—The chemical examination of some samples of spiegeleisen from Carinthia, in Austria, by H. Sturm, gave the following results:—

	From Sava.	From Eisenerz.		
Carbon... ...	4·50 ...	3·98	3·92	3·95
Silicon... ...	1·13 ...	not determined.		
Manganese ...	8·34 ...	18·15	7·73	9·70

Ferromanganese.—From Reschitza, in Hungary, analysed by H. Sturm, contained:—

Carbon	6·21
Silicon	0·28
Phosphorus	0·06
Sulphur	trace
Copper	0·14
Manganese	69·64
Iron	23·46
	99·79

TEMPERING STEEL.—M. Caron, in a communication made to the Academy of Science, in Paris, on the 20th November, 1873, expresses his opinion against the ordinary system of treating steel by hardening it first and then "letting it down" to the required temper, objecting to the plunging of the red hot steel into cold water as likely to produce cracks and flaws in it, and as unnecesary, declaring, as the result of many experiments, that an excellent temper is obtained by the single operation of plunging the hot steel into boiling instead of cold water.

Mr. George Hay has published in Pittsburgh, U.S., the results of some experiments which he has made in tempering steel, which lead him to the conclusion that not only is the amount of carbon contained in steel generally over-stated by chemists, but that steel in process of hardening absorbs more carbon from the fuel. He gives the results obtained from analyses of two different samples of steel in the soft state, and after they had been hardened by heating in a forge and immersion in water in the usual manner, as follows:—

Sample No. I.	Hard	0·429	...	trace	...	0·459	per cent.
	Soft	0·294	...	0·071	...	0·275	„
						0·184	„
Sample No. II.	Hard	0·544	...	trace	...	0·544	„
	Soft	0·319	...	0·030	...	0·357	„
						0·187	„

As these results are altogether at variance with the very common idea that, in the process of hardening, a portion of the carbon in the steel is actually burnt out of it, it would be interesting to have them confirmed by further experiments on the subject.

PUDDLING WITH COAL TAR.—The Marquette mining journal describes some recent experiments in puddling made at the Wyandotte rolling mills in Michigan, by using coal tar, in conjunction with superheated steam and atmospheric air. We extract the following account:—

An ordinary puddling furnace has its fire space banked up with brick, and on the top of the bank, near the level of the bridge,

the gases are introduced and burnt in the following manner. A tank of coal tar stands above the furnace, with a pipe leading from it to the opening on the level of the bridge, now forming the floor of the combustion chamber, through which the tar is allowed to drip slowly, where it is impinged upon by a jet of superheated steam issuing from a sixteenth or eighteenth-inch nozzle, the force of which also carries a certain quantity of atmospheric air along with it, the whole igniting and burning fiercely with a series of explosions like the rattle of musketry. The steam, which is superheated to a temperature of 1,800°, is delivered against the tar at a pressure of 60lbs. to the inch ; the volume of flame completely fills the puddling chamber at a white heat, and the iron is at once melted by it, and brought to the boiling point in an incredibly short time, the combustion being so complete that the entire gases are consumed. The steam is heated by passing from the boiler through a coil in the exit flue of the furnace, which keeps it at a red heat, and makes the steam literally red hot before it, in conjunction with the air carried in by its rush, impinges on the tar.

The iron made by this process is said to be close-grained, firm, and tenacious, and the expense of the coal tar used, at the price of three dollars per barrel, is estimated at 65 cents., or about two shillings and sevenpence per ton of iron ; according to Mr. Merriman this process has proved a success, and makes better iron at less expense, in shorter time than the ordinary puddling with coal.

Mechanical Puddling.—A lecture, on the progress made by Danks's puddling system in England, was given by Professor Jordan, on the 17th October, to the Société des Ingenieurs civils de France, in which a very excellent summary of the results of the working of these furnaces up to date, in this country, was communicated. A report of this lecture will be found in the Moniteur des Intérêts Materials for November 9th, 1873, to which we may refer,

Some attention was directed at the Vienna Exhibition to a model of Sellers' rotary puddling furnace, in the American department, a notice of which was given in our second quarterly report for 1872.

Puddling and Mill Furnace Slags.—The following analyses of these slags, from the ironworks of Reschitza, in Hungary, have

been made by M. Lill, and are extracted from the Berg-und Huettenmænnische Jahrbuch, Wien, 1873:—

	Puddling Furnace.		Welding Furnace.	
Silica	27·900	... ...	26·850	
Alumina	3·660	... ...	3·700	
Sesquioxide of Iron ...	10·000	Iron 46·36 °/。	8·400	Iron 38·78 °/。
Protoxide of Iron ...	50·600		42·300	
,, Manganese	0·280	... ...	0·280	
,, Copper ...	0·094	Copper 0·075 °/。	0·035	Copper 0·028 °/。
Lime	1·000	... ...	0·600	
Magnesia	0·310	... ...	0·100	
Alkalies	Traces.	... ...	Traces.	
Sulphur	0·048	... ...	0·096	
Phosphoric Acid ...	0·183	Phosphorus 0·080 °/。	0·056	Phosphorus 0·025 °/。
Entangled Coal ...	6·600	... ...	17·70	
	100·675		100·117	

ROLLING MILLS.—We observe that M.M. Gillon and Dujardin, of Liége, in Belgium, have patented, in England, their modification of the three-high rolling mill, under date of 19th March, 1873, No. 1,025. In this arrangement the lowermost roller is mounted in fixed bearings; the uppermost in adjustable ones, which are raised or lowered by strong screws at each end, worked by level gearing with a hand-wheel; and the middle roller in moveable bearings, capable of being raised or lowered in guides attached to the side standards. A rolling mill, on this system, was shown at the Liége meeting of the Iron and Steel Institute, and is a modification of the three-high mill of Lauth; descriptions, with drawings of both these mills, as erected in Belgium, will be found in the Chronique de l'Industrie, 1873, vov. II., p. 149-303.

Lauth's three-high rolling mills seem to be every day gaining ground over all other plate and sheet rolls in America. At Pittsburgh, Messrs. Singer, Nimick, and Co. have six trains of them in operation, and are rolling six-feet circular saw plates by them; Messrs. Graff, Bennett, and Co. are also employing them. At Baltimore, the Abbott Iron Company are using the largest train of three-high rolls in the States, turning out plates of any required thickness, seven feet in width. The members of the Institute present at Liége had excellent opportunities for seeing four trains of these three-high rolls in most successful operation at the Esperance Works, at Liége, where they have now completely superseded the old-fashioned sheet mills.

In *Engineering* for August 15, will be found a descriptive drawing of Danks' rolling mill engine, exhibited at Vienna.

A description, with drawings of the rolling mill engine, exhibited in Vienna, by the firm of Elglerth and Cunzer, of Eschweiler-Aue, in Rhenish Prussia, will be found in the number of *Engineering* for June 27th, 1873.

Cold Rolled Shafting.—Some excellent samples of this manufacture, made by Messrs. Jones and Laughlins, of Pittsburgh, Pennsylvania, were exhibited at Vienna, and deserve notice. Such cold rolled iron is now very much used in the United States for shafting, piston rods, &c., it being maintained that the process of cold rolling, besides being much cheaper than turning in the lathe, increases the strength as well as the hardness and elasticity of the metal in a marked degree, and the results of breaking tests seem fully to bear out this opinion. The manufacture is exceedingly simple: The bars after having been rolled down hot to about one-eighth of an inch of their ultimate dimensions, are pickled in acid to remove the surface scale, and reduced to the previously determined size by cold rolling, by which they acquire a highly polished and smooth surface. Tables of the breaking strength of such shafting, as compared with the same iron merely rolled as usual or turned in lathes, will be found in *Engineering* for August 1st, 1873.

Estimation of Sulphur in Coal and Coke.—In the fourth quarters' report for last year, a process for estimating the amount of sulphur contained in coals or coke, brought forward by G. W. Mixter, was briefly noticed ; since then Herr A. Sauer, of Bochum, has published in the Zeitschr. f. Analyt. Chemie, for 1873, p. 33, a modification of this method, which appears to be somewhat simple in execution. The process itself consists in burning the substance in a current of oxygen, and conducting the sulphurous and other gases thus produced into hydrochloric acid, to which bromine has been added. After the combustion is completed, a solution of chloride of barium is added to the absorbing liquid, the whole heated to drive off any excess of bromine, and the sulphur percentage calculated from the amount of sulphate of barium precipitated, which is determined as usual.

When the substance under examination gives off no volatile matter likely to contain sulphur, as in the case with coke, this

process is very simple, consisting merely in placing the substance in a porcelain tray in and near the middle of an ordinary combustion tube, about twenty-five inches long, one end of which is reduced in diameter, bent down at right angles, and connected with an absorption apparatus containing the acid bromine, whilst through the other a current of oxygen gas is conducted until the combustion is complete, and all gaseous or liquid products have been forced over into the absorbing liquid, which is then washed out into a beaker, and treated with chloride of barium as before stated. Any sulphur, which may be contained in the ash, which remains behind in the porcelain tray, is to be separately determined as sulphate of barium, after bringing it into solution by means of hydrochloric acid, or by fusion with carbonate of sodium in the usual manner.

When, however, as is the case with bituminous coals, the substance when heated evolves gasiform matter, which may contain sulphur, this process becomes somewhat more complicated, requiring a peculiar arrangement of the apparatus, in order to secure the oxidation of the sulphur in the gases also, and as this is difficult to describe without figures, we must refer to the original paper for full details.

Volumetric Estimation of Iron.—In many cases it is found more convenient to bring the iron into solution by means of hydrochloric acid, which solutions, however, are not well adapted for titration by the permanganate process. Mr. J. M. Crafts has published in the Bulletin de la Société Chimique de Paris, for July 20, 1873, a modification of the method of determining iron by means of hyposulphite of sodium, which appears to be both exact as well as rapid in execution.

The standard solutions required for the process are hyposulphite of sodium and sesquichloride of iron. The hyposulphite should be air-dried by exposure for several days spread out in thin layers on filtering paper, being re-pulverised every day in order to expose fresh surfaces, and exposed until it no longer looses weight in dry air, and then after its value has been determined by experiments, a normal solution can always be prepared by dissolving the corresponding quantity in water; if the salt is pure, 12·4 grammes will give a viginti-normal solution, which will keep its value for a month within 0·2 or 0·3 per cent.

The solution of sesquichloride of iron, which serves as a standard, is made by dissolving clean iron, whose percentage of carbon is known, in strong hydrochloric acid, then adding a few drops nitric acid, boiling for some minutes, and evaporating until the crust of ferric chloride, which forms, begins to re-dissolve with difficulty in the acid solution ; during the last ten minutes, it is necessary to watch carefully, so as not to pass the proper point. Solutions more concentrated than viginti-normal should not be used, and to make these it is necessary to dissolve in a litre of water 2·8098 grammes of fine iron wire, which contain 99·65 per cent. metallic iron.

The determination of the iron is made by adding the hyposulphite in known excess, and then titrating back with iodine to ascertain the excess of hyposulphite, using as nearly as possible the same excess of hyposulphite on each occasion; the reduction is complete in five or six minutes, its termination being tested by sulphocyanide of potassium, which should give no red coloration. The only cause of error to be feared is in the free acid of the ferric solution exerting a decomposing action on the hyposulphite; care must therefore be taken to reduce this excess of acid to a point at which its disturbing action becomes inappreciable. The well-known reaction between iodine and starch, which indicates when a sufficiency of iodine has been added, is not appreciably obscured by the volume of the liquid.

In practice, an iron ore is boiled with hydrochloric acid, oxidised with nitric acid, and then evaporated down to the point indicated above; a convenient quantity is 1·4 gramme, dissolved in half a litre; a preliminary titration serves to determine approximately, the quantity of hyposulphite solution equivalent to 100 c.c. of the ferric solution, and in the final operation, 20 per cent. more of the hyposulphite solution is employed ; water added during the analysis should be deprived of air by previous boiling. Ferric chloride, reduced to the ferrous state during an analysis by this method, may be exposed to the air for as much as twenty-four hours, without becoming sensibly oxidised.

Estimation of Manganese.—For determining the amount of this metal, when it is contained in very small quantity in iron, steel, or iron ores, Leclerc (Compt. rend., 75, p. 1209), Chatard (Zeitsch. Anal. Chemie, XI., p. 308), and Pichard (Compt. rend., 75, p. 1821) all agree in recommending that the manganese present

should be brought into the form of permanganic acid, by boiling with nitric acid and peroxide of lead, after which, it should be determined by titration or calorimetrically; Chatard employing a normal solution of oxalate of ammonia, for its volumetrical estimation, whilst Leclerc recommends a normal solution of the protonitrate of mercury, as this allows of titrating whilst cold, and permits its termination to be better observed. Pichard, on the other hand, prefers calorimetrical estimation, by comparing the colour of the solution with that of another of permanganate of potassium of known strength. It must, however, be remembered, that this method is only to be employed when the quantity of manganese present is very small, as, in case of a larger percentage, the conversion of the whole of this metal into permanganic acid, by boiling with nitric acid and peroxide of lead, cannot be altogether depended upon.

Kiesser (Moniteur Scientifique, Sept., 1873), remarks, that when the separation of manganese from iron is effected by the acetate process, the principal reason for the amount of manganese being given as too low, is due to the employment of too much acetate of sodium, in the precipitation of the iron. He finds 1 gramme acetate of sodium, to be sufficient for the complete precipitation of 1·1 gramme in 500 cubic centm. of the solution, even when 1 gramme of acetic acid is contained in it. If the amount of manganese is alone required to be determined, it is recommended that the liquid, when cooled, be made up in bulk to 500 c.c. by the addition of water, filtered through a dry filter, and the amount of manganese contained in it calculated from the results of its determination in 250 c.c., that is, one-half only of the filtrate.

December 31st, 1873,
11, York Place, Portman Square, London, W.

NOTES ON THE IRON AND STEEL INDUSTRIES OF THE UNITED KINGDOM.

Mineral Statistics of the United Kingdom.—Mr. Robert Hunt, F.G.S., the Keeper of the Mining Records, has lately issued the volume of the Mineral Statistics for 1872. From this it appears that, as far as regards the iron trade, 16,638,599 tons 2 cwts. of iron ore (of which returns were received) were raised in 1872, as compared with 16,859,063 tons 14 cwts. in 1871, and 14,370,654 tons 18 cwts. in 1870. The particulars are as under :—

Iron Ore Produce.

	1870. Tons.	Cwts.	1871. Tons.	Cwts.	1872. Tons.	Cwts.
Cornwall	11,214	4	21,947	14	48,199	19
Devonshire	10,193	17	14,124	14	29,361	0
Somersetshire	19,739	7	32,833	13	30,913	8
Gloucestershire	183,503	9	207,598	16	199,453	5
Wiltshire	101,423	0	159,894	0	96,117	10
Oxfordshire	38,803	17	28,330	0	63,536	0
Northamptonshire	761,248	0	779,314	3	1,004,093	7
Lincolnshire	248,329	17	290,673	9	318,802	0
Shropshire	337,627	0	415,972	0	408,425	0
Warwickshire	17,500	0	34,075	0	43,375	0
Staffordshire, North	910,134	0	1,513,080	0	361,603	0
Do. South	450,000	0	705,665	0	641,950	0
Derbyshire	384,865	0	492,973	0	307,183	0
Lancashire	871,938	0	931,048	0	852,064	12
Cumberland	1,221,303	4	1,302,703	15	917,452	9
Yorkshire N. Riding	4,072,888	1	4,581,901	0	4,974,950	10
Yorkshire W. ,,	307,717	0	407,997	0	466,305	0
Northumberland & Durham	225,332	0	285,297	0	97,953	13
North Wales	59,240	0	51,887	0	27,775	0
South Wales and Monmouthshire	560,055	2	969,714	10	1,247,594	0
Isle of Man	—	—	75	0	994	6
Scotland	3,500,000	0	3,000,000	0	3,270,000	0
Ireland	77,600	0	107,734	0	176,550	3
Total iron ore production of the United Kingdom	14,370,654	18	16,334,888	14	15,584,357	2
"Burnt ore" from cupreous pyrites	—	—	200,000	0	252,239	0
Iron ore imported	—	—	324,175	0	801,503	0
Total of iron ore of which returns were received	14,370,654	18	16,859,063	14	16,638,599	2

Pig Iron Manufacture.

The total quantity of iron ore smelted in Great Britain amounted, in 1870, to 14,578,964 tons; in 1871, to 16,859,063 tons; and, in 1872, to 16,539,889 tons.

Pig Iron Produced.

	1870. Tons.		1871. Tons.		1872. Tons.
In England	3,735,627	...	4,379,370	...	4,594,614
In Wales	1,021,888	...	1,087,809	...	1,057,315
In Scotland	1,206,000	...	1,160,000	...	1,090,000
	5,963,515	...	6,627,179	...	6,741,929

In 1872, the quantity of coal used in the production of this pig iron was :—In England, 11,388,342 tons; in Wales, 2,607,887 tons; and in Scotland, 3,215,500 tons; or a total of 17,211,729 tons. Coke has been computed as coal.

The average number of furnaces in blast in England during 1872 was 449¾; in Wales, 122¼; and in Scotland, 130; total, 702.

Summary of Pig Iron Produce.

Counties.	1870. Tons of Pig Iron made.	1871. Tons of Pig Iron made.	1872. Tons of Pig Iron made.
England—			
Northumberland	33,623	34,165	38,766
Durham	676,964	759,244	760,172
Yorkshire, North Riding ...	916,970	1,029,885	1,122,114
Do. West Riding ...	77,717	114,549	148,636
Derbyshire	179,772	270,485	283,375
Lancashire	422,728	520,359	524,041
Cumberland	255,178	336,569	440,575
Shropshire	112,300	129,467	133,046
North Staffordshire	303,378	268,300	275,925
South Do.	588,540	725,716	673,470
Northamptonshire	43,166	60,512	59,424
Lincolnshire	31,690	30,122	36,989
Gloucestershire	93,601	99,998	46,226
Wiltshire			44,255
Somersetshire			7,600
Total	3,735,627	4,379,370	4,594,614
North Wales—			
Denbighshire	42,695	41,893	41,464
Flintshire	—	—	13,228
South Wales—			
Anthracite furnaces	28,500	34,761	25,678
Bituminous coal districts—			
Glamorganshire	478,243	510,087	465,603
Brecknockshire	472,450	30,086	30,000
Monmouthshire		470,982	481,342
Total	1,021,888	1,087,809	1,057,315
Scotland	1,206,000	1,160,000	1,090,000

The following is a summary of puddling furnaces in operation in the years 1870, 1871, and 1872:—

Counties.	1870. No. of Puddling Furnaces.	1871. No. of Puddling Furnaces.	1872. No. of Puddling Furnaces.
Northumberland	54	44	54
Cumberland	95	89	86
Durham	951	1,053	1,135
Yorkshire (Cleveland district)	542	529	492
Do. (Leeds and Bradford district)	247	236	282
Do. (Sheffield and Rotherham district)	353	342	363
Derbyshire	94	91	108
Somersetshire	19	19	19
South Staffordshire	2,037	1,934	2,155
North Do.	429	406	446
Shropshire	218	206	184
Lancashire	154	192	178
North Wales	54	54	66
South Wales—			
Glamorganshire	613	568	594
Brecknockshire	86	62	20
Monmouthshire	553	535	637
Scotland	339	339	486
Total	6,841	6,699	7,311

The number of rolling mills to which the furnaces in 1872 worked was 1,015.

Coal Production of the United Kingdom.

The statistics relating to the production of coal, during the year 1872, will be of interest. Mr. Hunt furnishes the figures which were returned to the inspectors in the various districts at the close of that year. In 1870, he shows that 110,431,192 tons were raised; in 1871, 117,352,028 tons; and, in 1872, 123,497,316 tons. As an alteration has been made in this issue of the statistics in the classification of the various districts, we only give the detailed returns for 1872, which are as follows:—

	Tons.
North Durham, Northumberland, and Cumberland	13,010,000
South Durham	17,395,000
Yorkshire	14,576,000
Derbyshire, Nottinghamshire, Warwickshire, Leicestershire	10,657,100
Staffordshire, South, and Worcestershire	10,550,000
Staffordshire, North, Cheshire, Shropshire	6,327,188
Lancashire, North and East	9,363,236
West Lancashire and North Wales	9,000,000
Gloucestershire, Somersetshire, Monmouthshire	7,000,000
South Wales	10,131,720
Scotland, East	9,046,814
Scotland, West	6,336,795
Ireland	103,463
Total produce of the United Kingdom	123,497,316

The figures for Ireland are estimated, as the Act for that country did not come into operation until the 1st January, 1874.

DYNAMITE.—Early last year, a company, styled the British Dynamite Company, was formed amongst gentlemen prominently connected with coal, iron, and other metalliferous mines, with limestone and other quarries, and with railway engineering, &c., for the purpose of manufacturing and introducing into this country an explosive, invented by M. Alfred Nobel, a Swedish engineer. Dynamite owes its utility, as a blasting agent, to the presence of 75 per cent. of its weight of nitro-glycerine. It is used largely on the continent, and in several mining districts of this country; more particularly, in the hematite ironstone mines of Cumberland and Lancashire. The works have, since the formation of the company, been erected at Ardeer, in Ayrshire, and have been licensed by the Home Secretary, under the Nitro-glycerine Act. The peculiarity of the substance is, that it will not explode when loose; it requires to be packed tightly, when it is to have any effect.

SUPPOSED GLACIAL ACTION ON DEPOSITION OF HEMATITE IRON ORE.—At a meeting of the Manchester Literary and Philosophical Society, Mr. William Brockbank, F.G.S., read a paper entitled "Notes on supposed Glacial Action in the Deposition of Hematite Iron Ores in the Furness District." In this communication he showed that there are in Furness two distinct varieties of ore.—1st, that filling hollows in the limestone, covered only by the post-tertiary gravels and clay; and, 2nd, that occurring in the carboniferous limestone in veins, and large irregular cavities or pockets. The second, or regular veins are easily accounted for, but, the first or superficial deposits, the writer thought, afford undoubted evidence of glacial action, and of the mode in which the iron ore has been transported by its agency. As illustrative of the district, he gives a section, which shows that under 6 feet of soil, gravel, and clay, or yellow clay, a layer 4 feet thick is found mixed with iron ore; then follows 4 feet of black mould, and next dark coloured iron ore 2 feet thick, under which comes 6 feet of black mould, mixed with iron ore, and then 8 feet of ironstone. Underneath these lie limestone, &c., of a thickness of 27 feet, and below this again the regular veins of hematite ore. The occurrence of these superficial deposits is, he believes, to be explained by the theory of glacial action, and is evidently part of the great change wrought upon the surface by the agency of ice,

during the glacial epoch coeval with the boulder drift. The great ice sheet, which then covered all the North of England, descended from the lake mountains, grinding down the surface rocks, and depositing the clays and gravels in its course. The ore occurring in these deposits is of a dark colour, and has the appearance of having been all ground to powder. After exposure to the air it soon falls into this state. The water, resulting from any thaw of the ice, would carry the ore down with it into the crevices and caverns of the limestone, where it is found as soft or "puddling" ore.

Formation of Clay Ironstones.—Mr. J. Lucas, F.G.S., read a paper before the Geological Society on "Clay Ironstones," and gave a general view of their varieties, chemical composition, and mode of occurrence. He suggested that the formation of all the bedded varieties could be explained by the supposition that they originated in peaty or non-peaty lagoons on the alluvial flats of the deltas of the carboniferous formations, which would present semi-terrestrial conditions, *i.e.*, a surface exposed to the air, but subject to be covered by floods. Carbonic acid formed in the lagoons from decomposing vegetable matter, meeting with protoxide of iron in solution, would unite with it to form carbonate of iron, which, with the mud of the lagoon, would produce clay ironstone. Thus the beds of clay ironstone, like coal beds, mark terrestrial horizons. In the discussion, Professor Ansted thought that though satisfactory for instances of limited thickness and confined area, this theory was not applicable to the far larger deposits, like those in America, extending over hundreds of square miles, and of great thickness. Professor Ramsay considered the theory proposed by the author was quite in accordance with the assumption of the estuarine character of the deposits. He did not agree with him that ironstone was never deposited in marine strata, as they occurred in the Yoredale beds, and in some Liassic measures. As to the deposits of ironstone in fresh water, he referred to those still taking place in some of the Swedish lakes. Mr. David Forbes corroborated the remarks of Professor Ramsay.

New Mineral Field in North Devon.—A new mineral district is being opened up in North Devon, near the villages of North and South Molton, a part already traversed by the Somerset and Devon Railway, which runs almost parallel with the lodes of

iron ore. The deposits consist of red hematite and spathic carbonate of iron, and various firms have obtained concessions for working portions of them. The ores are almost identical in composition with the spiegel ores found in Germany. In some of the specimens taken out from near the surface, there is a marked quantity of silica, but when got at some depth there is very little. An analysis of one specimen shows that the white or spathose iron ore contains 29 per cent. of protoxide of iron, and another gives 55 per cent. of carbonate of iron, with 24 per cent. of carbonate of manganese. The ferro-manganese ores give 70 per cent. of peroxide of iron, and nearly 17 per cent. of peroxide of manganese.

Bowling Iron Works.—At the meeting of the British Association, at Bradford, in the autumn, Mr. E. H. Carbutt, of that town, read before the Mechanical Section a paper prepared by Mr. Wilcock, "On the history, progress, and description of the Bowling Iron Works, Bradford." In this it was stated that the works comprise six cold blast furnaces, from which 360 tons of pig iron are run per week, five refineries, 21 puddling furnaces, 40 heating furnaces, an extensive forge, a tyre mill for rolling steel and iron weldless tyres, one guide mill, one bar mill, with 15-inch rolls, and two plate mills. A third plate mill is nearly ready, which will have Ramsbottom's reversing engines. There is also an extensive steel works for making crucible steel, and an engineering establishment. The Bowling Iron Company has its own collieries and ironstone mines, and the number of hands employed by them is upwards of 3,000. The yield per cent. on the raw ore is 32 per cent. of iron, and on the calcined ore 42 per cent. The following are the relative quantities of minerals for producing one ton of Bowling pig iron :—Raw ore, 3 tons 3 cwt. 3 qrs. 27 lb.; or calcined ore, 2 tons 7 cwt. 1 qr. 26 lbs.; limestone, 18 cwt. 2 qrs. 12 lbs.; coke, 2 tons 5 cwt. 0 qrs. 9 lbs. The quantity of pig iron used to produce 1 ton of bar iron (finished) is 1 ton 12 cwt. 1 qr. 25 lbs. The process of making the Bowling iron weldless tyres is fully described in the paper.

Redesdale Ironstone.—A paper, on the "Geology of the Redesdale Ironstone District in Northumberland," has been read before the North of England Institute of Mining and Mechanical Engineers, at Newcastle, by Mr. G. A. Lebour, F.G.S., F.R.G.S., of Her Majesty's Geological Survey. The author, was, for some years,

employed in investigating the geology of West Northumberland. He states, that the area included in this district comprises 15 square miles, drained by the Redewater. The sedimentary rocks thereunder are sandstone, limestone, coal, shale, and fire-clay—all belonging to the carboniferous limestone series. Igneous rocks are represented only by a little "whin dyke," basalt, three feet thick. The section of the rocks which actually crop out in the district is as under, beginning with the topmost bed:—(1) sandstone; (2) shale, with thin calcareous bands; (3) hard splintery calcareous bed; (4) sandstone; (5) shale; (6) limestone. These beds occur on the summit of Buteland Fell. There is here a long fault—the Cock-play fault—and near it the dip is high, and is abnormal in direction, being about 15 degs. in amount and south-easterly, whereas just east of Buteland the dip is from 4 to 5 degs. only, and in a southerly or south-easterly direction. The limestone has been quarried extensively for burning purposes, and is about 20 feet in thickness. Below this limestone is a sandstone stratum, and next a very thin bed of impure limestone, which is worth mentioning, because of its constancy and its peculiar aspect and fossils, which would make it useful as a guide in following the outcrops of the other underlying more important rocks. Under this is another bed of sandstone, of unequal thickness, immediately overlying a bed of shale, at the base of which is a seam of coal about 2 ft. 6 inches thick, and known locally as the top seam, or sometimes as the Fourlaws coal. This is the seam which, in his general section of what he termed "the upper series of coal beds," the late Mr. Thomas John Taylor called erroneously the "Hareshaw Head Seam." This bed of coal has been worked to some extent along its line of outcrop, especially all along the face of the Fourlaws Edge escarpment, where its outcrop is clearly shown by a line of old levels. It crosses the Watling Street just at the Dun Cow public-house; thence it curves round the head of the Broomhope Valley, the southern flank of which it follows, cutting across the Steel Burn and Linen Cleugh, sweeping away to the south from the latter streamlet, and turning down along the side of the greater North Tyne valley, where it and its subjacent beds are lost under the great accumulation of drift clay which obscures that part of the country. Its horizon, however, can be easily followed, and it can safely be drawn as far as the Heugh Burn. This coal crops out in two or

three other places in the northern corner of the district, notably for a little distance east and south-east of the White Crag, and north of the High House, across Chesterhope Burn. In the railway cutting by the Crag Farm, however, this coal is well seen, and its relations to the beds immediately below it can be easily studied. Crossing the Redewater below the crag itself it runs hidden under a great thickness of drift on the opposite side of the valley to Conheath, where it has been worked, thence turning up the side of the Hareshaw Burn valley, and close to Hightown, where it is cut off by an east and west fault. This bed of coal is one of the most important in the district, one that has been worked and is worked at the present time. It may also be said to have a guiding bed. This guiding bed to the Fourlaws coal is a limestone separated from it by thick shales and thin sandstones rarely exceeding 50 feet—which limestone is known locally as the upper or top limestone. Then follows another bed of sandstone and shale, in some places 90 feet thick, and below this again the bottom limestone, and under it a stratum of sandstone 11 feet thick, after which is found the iron-bearing shale. This is 30 feet thick, having occasionally at its base a few inches of coal, and having always in its upper half a coarse band, commonly called "Shell Band" from its being entirely composed of fossils. Throughout the shale, both above and below the shell band, are nodules of clay ironstone of every imaginable shape, but usually more or less flat and uniform or lenticular, and ranging from the size of a pea to a ball 50 lbs. weight. The beds below these, though including a thin coal or two, are not of any importance. The chief source of the intricacy of the Redesdale district is its system of faults, which are now found to be of two kinds, generally running in a more or less east and west or north-east and south-west direction. Mr. Lebour, after describing the faults, states that the nodules of ironstone have been largely worked in open-face workings, the limestone above being quarried at the same time for agricultural purposes. Now, however, the workings are chiefly underground, being carried on by levels as the baring or cover had become too great. The limestone contains 95·47 per cent. of carbonate of lime, 1·16 per cent. of protoxide of iron, and 10 per cent. of iron pyrites. In this district the Hareshaw and Redesdale Iron Works have been carried on for a number of years, but the former are now dismantled.

Magnetic Iron Ore in Bute.—At the meeting of the Royal Physical Society of Edinburgh, in December last, attention was called to a remarkable deposit of magnetic oxide of iron occurring on the island of Bute, at Bogany Point, near Rothesay Bay. Mr. Cameron, of Rothesay, noticed on the beach there an unusual kind of blacksand, and taking a specimen, which he dried and carefully examined, he found it to consist of pure, but finely divided magnetic iron ore. It was remarked that this sand is very plentiful at the place named.

The Exhaustion of the South Staffordshire Coalfield.—At the October meeting of the South Midland Institute of Engineers, Mr. Daniel Jones, an honorary member of the Institute, and Secretary of the South Staffordshire Ironmasters' Association, called attention to the exhausted condition of the South Staffordshire coalfield, and particularly of that most famous seam, the Dudley Thick-coal. It was only recently that the public had been willing to realise this fact, to which Mr. Baker, Her Majesty's Inspector of Mines, had prominently referred in his reports. The Dudley Thick-coal was not less important from a geological point of view than from the economic. The puzzling question of how 30 feet of pure coal had been amassed without any intervention of strata had not yet been answered. It was a subject to which the Mining and Geological Societies in South Staffordshire would do well to address themselves, for he believed that the strata of the earth were like the printed pages of a book, which, if carefully studied, would give their own explanation. The good which might be expected to result from this would be, that they would be guided where to look with confidence for a thick seam similar to that which was being so rapidly used up. It would be said that they knew already of a coalfield over the western boundary fault. There were yet many matters to clear up on that point. For instance, he should desire to know whether there would be any coal measures overlying the thick coal; or was it to be expected that when they had pierced the Permian they would find the first coal measures near to the thick coal? They were all aware that the thick coal cropped out in the neighbourhood of Wolverhampton, on the top side of the western boundary fault. Would that outcrop be continued under the Permian or not? Of course, the enquiry was involved in the question whether the disturbance and denudation giving rise

to this outcrop happened before or after the deposition of the Permian. If they had to sink through the upper coal measures before reaching the thick coal, they might have 200 yards more ground to sink through than they counted upon. The stratigraphical enquiry connected with the dividing and splitting up of the thick coal soon forced upon them the question of co-relating this with other districts, and also the very important enquiry as to the original shape of the coal basin and the indications of this district being on the margin of the coal swamp. This was most necessary when considering the probabilities of the thick coal extending to the east and the south. He was fully convinced in his own mind that there was no thick coal whatever east of the Sandwell pits, although he hoped that speculation might be successful and his convictions upset. He thought there could be no doubt of the Silurian margin of the basin ranging there. This margin was high ground, as left by denudation in pre-carboniferous times, and the coal measures at the level of the thick coal only abutted against it. The original surface upon which the Shropshire and Staffordshire coalfields were deposited was a table-land, which sloped down to much lower ground further northward. This they knew, because it was low enough to receive carboniferous limestone and millstone grit. These level formations were always an element of regularity in the succeeding coal measures. Now, much information might be gleaned by an intelligent examination of the changes in the strata and the structure of coal seams. Thus, a rapid deterioration of the thick coal into a mere mud heap and its tendency to divide were to him unerring indications of the marginal boundary of the swamp being at no great distance. This he believed to be the state of things existing to the east and south of the coalfield. There were indications to show that the escarpment, after passing to the south near West Bromwich and Sandwell, turned across the southern boundary of the coalfield, and passed away towards Bewdley. When he made his official surveys at the Forest of Wyre coalfield, he obtained a pit section 454 yards deep. Now the main sulphur coal of that district was found at 834 feet from the bottom of the shaft. The same coal further south, at Arley Kings, rested within a very short distance of the old red sandstone base. He considered this clearly showed that the floor of the basin rose to the south, and he believed

this to be the continuation of the escarpment he had before mentioned. A line drawn through West Bromwich, Sandwell, south of Hales Owen, and Wassel Grove, and then on to Bewdley, would approximately represent the line of this escarpment. He thought there was yet much to be done in working out details of this character; and it had occurred to him that much valuable information might be evoked by the offer of a prize for the best essay on the development of the South Staffordshire coalfield. The three Mining and Geological Institutes existing in South Staffordshire ought to combine in promoting this work. If they did, then he felt assured that, strengthened by the assistance of others, it would be carried into effect. He had communicated with the Secretary of the Dudley Mining Institute, who, in promising to lay it before their Council, had much approved of the suggestion. He should be glad if this Institute would consider the proposals he had already made in writing to Mr. D. W. Lees, their Secretary, at some future meeting of their Council.

GERHARD'S PROCESS.—Mr. F. W. Gerhard has introduced at Bradley, South Staffordshire, his process of manufacturing iron. He uses a compound which he terms "iron coke." The author states that his process dispenses with the melting and boiling of the iron, and that there is nothing to be done but the balling. A heat can be got ready in half-an-hour.

RILEY AND HENLEY'S PUDDLING PROCESS.—Messrs. Riley and Henley have recently patented an improved method of puddling, which has been put in operation at the Pontnewynydd Iron Works, near Pontypool. The object of the invention is to reduce the extreme manual labour attending the production of wrought iron in the ordinary puddling process. The body or hearth of the furnace on which the materials are heated consists of a circular pan with slanting sides. This revolving pan is fixed on a vertical spindle, and worked with the aid of bevil gearing by a very small engine, the number of revolutions of the pan being under the direct control of the puddler. The pan is so fitted that air cannot enter the furnace except at the working hole of the door. This puddling furnace is, with the exception of the revolving bottom and its connections, built up and stayed by plates and bolts like the ordinary puddling furnace, only that the back and front plates at the middle of the furnace are cut off about the bottom of the

hearth to admit cool air under the pan. The tools used are nearly like those of the ordinary process, but the rabble has a projecting pin, which is caused to rest against the inside of the rabble-hole, in order to obtain a hold against the revolving mass of iron melted in the pan. The other principal tool used may be called a "plough," because it is something in the shape of a ploughshare and causes the metal to be turned over, broken up, and cleared after beginning to "form" or "drop into nature." This tool, also, has a pin which holds it as in the previous case. The manipulation is as follows: —The furnace having had a small dressing of hammer slag and ground bulldog, is set slowly revolving, and the puddler throws in his half pigs in regular course so that they are equally distributed over the floor of the pan. The melting process then goes on as usual, but the revolving pan sucks the flame after it, and gives a more uniform and intense heat throughout the whole body of the furnace, and therefore the melting is quicker. Before the melting is complete, a boy breaks up the unmelted pieces of pig iron, and mixes them as they pass the working hole with the melted pigs, and in a few minutes the whole mass is in a state of fluidity, circling round in the pan, but travelling from its density at a slower pace than the bottom of the furnace, and consequently presenting fresh surfaces continuously to the flame. When melted, the puddler takes his rabble and fixes it in the hole in the door-plate, and inserts it in the fluid metal, directing it from the circumference to the centre of the pan, and *vice versa*: thus stirring the metal by the end of the tool, with little or no exertion on his part, or he turns it in the opposite direction, and rakes it up from the bottom as it passes. When the metal is coming to nature he removes the rabble, and puts in, and fixes as before, the "plough," which he presses to the bottom against the stream, causing the plastic material to roll over the tool in the form of a small cascade. The metal being "fit," the balling-up is set about. The revolving pan is stopped; the iron in front of the door is formed into a ball, the furnace is then turned round one sixth or so; another ball made, and so on, till the whole of the iron is balled up.

Mr. C. W. Siemens on Fuel.—During the meeting of the British Association at Bradford, Yorkshire, last autumn, Mr. C. W. Siemens, D.C.L., F.R.S., delivered a lecture on "Fuel." He divided his lecture into five heads: (1.) What is fuel? (2.) Whence is fuel

derived? (3.) How should fuel be used? (4.) The coal question of the day. (5.) Wherein consists the fuel of the sun? Fuel, he said, in the ordinary acceptation of the term, is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which in combining with oxygen, gives rise to the phenomenon of heat. Commonly, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. But combustion is not necessarily accompanied by flame, or even by a display of intense heat, The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is a solid, viz., oxide of magnesia. Metallic iron, too, if in a finely divided state ignites when exposed to the atmosphere, giving rise to the phenomena of light and heat without flame, because the result of combustion is iron oxide or rust. Fuel, he continued, is derived through the solar energy acting upon the surface of the earth. In speaking on the head of "How should fuel be used?" he sub-divided this into three parts—(1) the production of steam furnace; (2) the domestic hearth; and (3) the metallurgical furnace. The following are his remarks on the third section:—"The smelting or metallurgical furnace consumes about 40,000,000 tons of the 120 million tons of the fuel produced. Here there is great room for improvement, the actual consumption of fuel consumed in heating a ton of iron up to the welding point, or of melting a ton of steel, is more in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at ·114 and the welding heat at 2,700 degs. Fahrenheit, it would require 2,700 by ·114 = 307 heat units to heat 1 lb. of iron. A pound of pure carbon developes 14,500 heat units, a pound of common coal 12,000, and therefore one ton of coal should bring 39 tons of iron up to the welding point. In an ordinary re-heating furnace a ton of coal heats only $1\frac{2}{3}$ ton of iron, and therefore produces only 1-23rd part of the maximum theoretical effect. In melting one ton of steel in pots $2\frac{1}{2}$ tons of coke are consumed, and taking the melting point of steel at 3,600 degs. Fahrenheit the specific heat at ·119 it takes ·119 by 3,600=428 heat units to melt a pound of steel, and taking the heat-producing power of common coke also at 12,000 units, one ton of coke ought to be able to melt 28 tons of

steel. The Sheffield pot steel-melting furnace, therefore, only utilises 1-70th part of the theoretical heat developed in the combustion. Here, therefore, is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. I have, since the year 1846, or very shortly after the first announcement of the dynamical theory, devoted my attention to a realisation of some of the economic results which that theory rendered feasible. I fixed upon the regenerator as the appliance which, without being capable of re-producing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilised in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating or of generating force. Without troubling you with an account of the gradual progress of these improvements, I will describe to you shortly the furnace which I now employ for melting steel. This consists of a furnace bed made of very refractory material, such as pure silica sand and silica or Dinas brick, under which four regenerators or chambers filled with checkerwork of brick, are arranged in such a manner that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoining regenerator in order to meet in combustion at the entrance into the furnace chamber. The products of combustion, instead of passing directly to the chimney, as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300 deg. Fah.) After going on in this way for half-an-hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerator in the reverse order in which it was deposited, reaching the furnace, therefore, nearly at the temperature at which the gases of combustion left the same. A great reversion of temperature within the chamber is the result, and the two first mentioned regenerators are heated to a higher degree than the latter. It is easy to conceive that, in that way, heat may be accumulated within the chamber to an apparently unlimited

extent, and with a minimum of chimney draught. Practically the limit is reached at the point where the materials composing the chamber begin to melt. Whereas, a theoretical limit also exists in the fact that combustion ceases at a point which has been laid by St. Clair Deville at 500 degs. Fah., and which has been called by him the point of dissociation. At this point hydrogen might be mixed with oxygen, and yet the two would not combine. To return to the regenerative gas furnace. It is evident there must be economy where, within ordinary limits, any degree of heat can be obtained, while the products of combustion pass in the chimney only 300 degs. hot. Practically, a ton of steel is melted in this furnace with 12 cwt. of small coal, consumed in the gas-producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating, which is now extensively used in this and other countries, are, that no smoke is produced, and that the works are not encumbered with solid fuel and ashes. It is a favourite project of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas-producers at the bottom of coal-pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure, that it might be conducted to a distance of several miles to the works, or places of consumption. This plan, so far from being dangerous, would ensure a very perfect ventilation of the mine, and would enable us to utilise those waste deposits of small coal, (amounting, on the average, to 20 per cent.) which are now left unutilised within the mine. Another plan of the future which has occupied my attention, is the supply of towns with heating gas for domestic and manufacturing purposes. In the year 1863, a company was formed, with the concurrence of the Corporation of Birmingham, to provide such a supply in that town at the rate of 6d. per 1,000 cubic feet; but the bill necessary for that purpose was thrown out in committee of the House of Lords, because their lordships thought that if this was as good a plan as represented to be, the existing gas companies would be sure to

carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realisation of the plan itself has been indefinitely postponed.

The Sub-Wealden Exploration.—Mr. Henry Willett read a paper at the autumn meeting of the British Association on this subject. The object is to explore the rocks underlying the Weald of Sussex. The bore had reached the depth of 300 feet, about 70 feet of the strata of rubbish were known, but the remaining 230 feet were not then determined. About 50 feet of this consists of valuable beds of gypsum. He gave some reasons for supposing that near and to the South of Boulogne, some of the coal measures might be preserved in the basin of palæozoic rocks. The President, in the course of the discussion, said it seemed quite possible that coal might be found under Hampstead Heath. [Since the meeting, considerable progress has been made in this exploration. The boring is now in the oolitic formation.]

Siliceous Nodular Brown Hematite in County Tyrone.—At a meeting of the Royal Geological Society of Ireland, Mr. Edward T. Hardman, F.R.G.S.I., of the Geological Survey of Ireland, read a paper, the full title of which was "The Occurrence of Siliceous Nodular Brown Hematite (Gothite) in the carboniferous limestone beds, near Cookstown, County Tyrone; and note on its formation, by chemical alteration, from ordinary Clay-ironstone." The author said this ore had been known and worked 250 years ago. It is now seen at Cookstown, where traces of old workings are numerous. The nodules are mineralogically very peculiar. They are usually in the form of a hollow shell of about a quarter of an inch in thickness. The greater part of this is made up of a very hard, compact, siliceous brown hematite of a dark brown colour, but the interior is covered with a thin coating of fibrous and mammilated limonite. The shale in which they occur is generally ochreous red, and seems to be highly ferruginous. Being apparently very aluminous, as well as in parts calcareous, the author thinks that it might advantageously be used as a flux for the ore, and in this way the whole bed might be utilised. On analysis the ore yields over 60 per cent. of metallic iron. There is a total absence of sulphur, and the merest trace of phosphoric acid; thus the ore is extremely well suited

for the production of Bessemer steel. It also appears to be adapted for admixture with clay ironstone, or with the aluminous ore of Antrim. On the Southern shore of Lough Neagh some very hard and compact ironstones are found, sometimes of a slightly greenish colour, and appearing to consist chiefly of proto-silicate and carbonate of iron.

THE COAL COMMITTEE'S ENQUIRY.—Early last year, a Select Committee was appointed by the House of Commons for the purpose of enquiring into the causes of the existing dearness and scarcity of coal, and after taking the evidence of many gentlemen connected with the iron, coal, and other industries, they presented a report, which stated that in the document submitted in July, 1871, by the Royal Commission of 1866, it was ascertained by the most careful examination of the coal-fields of Great Britain, and the production of the mines at work in them, that there was abundance of coal for the present as well as for the future for many years to come, but the possible failure of the supply at some distant period was the subject of much speculation. The committee, however, limited their enquiry last year to the period immediately associated with the current condition of the coal supply. They compiled a table, showing the progressive increase of the population, and of the coal supply and consumption of coal, as well as the computed rate of consumption per head of the population of Great Britain during the fifteen years, from 1858 to 1872 (both inclusive). In this table, the number of inhabitants in Great Britain was put down as 22,498,956 in 1858, and 26,472,225 in 1872, while the consumption of coal per head was 2 tons 9 cwts. 3 qrs. 24 lbs. in 1858, and 4 tons 1 cwt. 1 qr. 1 lb. in 1872. The quantity of coal raised had nearly doubled, being only 64,587,989 tons in 1858, against 123,386,758 tons in 1872. In the first-named period, we exported about 8,600,000 tons, and retained for home consumption nearly 56,000,000, and in the latter year we shipped 15,800,000 tons, and consumed 107,562,000 tons. The committee examined some of the most experienced colliery proprietors and managers, whose evidence acquired additional weight from the fact, that some were selected as representative witnesses by important bodies of coal-owners. These gentlemen concurred generally in the opinion, that there had been considerable disturbance in the minds of the workmen employed in and about the mines, respecting the

number of hours per day or week during which the workmen deemed it to be their interest to work, and the general tendency had been to reduce the hours of labour. They stated, too, that the Mines Regulation Act, 1872, had tended to the same result, the consequence being that the mines had not produced the quantity of coals that could have been got from them. The Committee gave in a table showing that while the output per man had been 309 tons in 1858, and 321 tons in 1870, it had only reached 299 tons in 1872. They considered that one of the greatest benefits which could be conferred on the mining population was to induce them to work with regularity day by day, and for such a time daily as, while it would not detoriorate their health, social comfort, or moral condition, would not result in idleness or dissipation; but as no standard could be laid down to fulfil these conditions, it should be left to the general feeling of the workmen, improved by education, to arrive in concert with their employers, at the proper limits for their labour. The Committee, however, hoped that when the employment of the men had adjusted itself to the requirements of the new law, and to their desire for improving their condition, the aggregate result of the labour of the mining population would not be less than in former times. They said also that there was no doubt of the capacity of the existing collieries to keep up the current supply of coal, and that with an adequate provision of suitable labours the supply could be largely increased. New works were being opened out all over, and the Committee saw no reason to doubt that the collieries existing, and those likely to be opened up, would be capable of producing a large increase of marketable coal. Relative to the double shift system they elicited information to the effect that it tends both to increased facility and greater economy of production. The Committee hoped that when the advantages of the double shift system were fully understood amongst the workmen, it might be more extensively employed under conditions which might be satisfactory to the colliery owners and their workmen. Evidence was adduced respecting several matters exercising an influence over the general result of coal mining operations, such as the difficulty of obtaining residences for the workmen, or any sudden expansion of the number employed, the difficulty of draining mines when the workings of different proprietors adjoined each other, and were affected by the

same influx of water, the difficulty of obtaining increased means of transport in case of any sudden increase of demand for it, &c., but they did not deal with these questions fully. The general conclusions they drew from the whole evidence were that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet if an adequate supply of labour could be obtained, the increase of production would soon keep pace with that of the last few years. With regard to the consumption of coal, the Committee submitted figures obtained from Mr. Robert Hunt's Statistics, which went to show that in 1871, out of the 117,000,000 tons raised, 85,371,000 tons were consumed in our manufactories and for steam purposes, while for domestic purposes 16,639,000 tons were used. The consumption per head in the London district in 1872 was 1 ton 9 cwts. 2 qrs., and in 1869 it was 1 ton 7 cwts. 1 qr. 7 lbs. In the first-named year 3,977,569 tons were received, and in the second 3,760,501 tons. This Committee remarked that the former Commission had found that there were constant and persevering efforts made to economise coal by the application of improved appliances for its consumption, and the Committee had reason to believe that in some branches of manufacture the limits of a beneficial economy appeared to have been nearly reached, also that in other cases a gradual effort would continue to be made for saving fuel. The late Commission, however, considered that the increase in the consumption of coal would be diminished still further by greater economy in its use. The Committee found that the special branch of manufacture, which extended the demand for coal to a degree which could not be met by producers, and which led to a rise in the price of coal, was that of pig iron and its conversion into the various forms of rolled iron, and that this increase of demand mainly came from the United States of America and from Germany. A statistical table giving the production of pig iron, the exports of pig iron, the amount of pig iron left for conversion into rolled iron, the rolled iron exported, the coal used in the manufacture of pig iron, at 3 tons per ton of pig iron, the coal required to convert the pig into rolled iron, at 3 tons 7 cwts. per ton of bar iron, and the total coal used in the manufacture of iron during the last six years, shows that in 1867, the quantity of pig iron produced was 4,761,023 tons,

and the coal used amounted to 28,331,977 tons, while in 1872, the pig iron reached 6,723,387 tons, and the coal, 38,228,875 tons. The report then went on to say:—"The exact effect of the iron manufacture and trade on the coal market is best shown by the evidence of Mr. Isaac Lowthian Bell, largely connected with iron-works on the Wear, Tyne, and the Tees, who thus describes the rise in the price of pig iron, and the consequent rise in the price of coal. 'You come to the conclusion that the source of the sole disturbance was in the great increased demand for pig iron, and malleable iron, and manufactured iron?—I do not say the whole cause; it was one of the causes. Of course, a coalfield which had no ironfield would not have been affected by it; but we know a greatly increased demand has been felt everywhere. With us, no doubt, the iron trade gave a great stimulus to the coal trade, and I think the coke in our neighbourhood, in consequence, rose much higher than the coke in any other district. But the fact is, all industry all through the country has been, and still is, I may say, in a very flourishing condition, and the iron trade with others. The manufacture of alkali, in the North of England, is in a very flourishing condition; and, again, the increase of railways, and the general substitution of steam for sailing vessels, all added to demands on an output not very greatly increasing, have, I conceive, led to the present state of things.' 'Then, in your view, it seems that the iron trade primarily, and other trades in a less degree, caused an increase of demand with greater rapidity than the production of the coal?—Certainly, in the North of England it was so. In September, 1871, forge pig iron was selling with us for 50s., and coke was selling at from 10s. to 12s. a ton; pig iron rose gradually towards the end of the year to 46s., but coke was not affected up to that time. In January, pig iron rose from 64s. to 70s. and coke rose to 20s. In March, forge pig iron was 84s., and coke was 25s. In April, the pig iron rose to 94s., and the coke rose to 32s. 6d. In July, forge pig iron rose to 110s.; more than twice what it was in 1870, nine months before; and the coke rose to 37s. 6d. and 41s. per ton. Now, pig iron rose in spite of the increase in the quantity made; that is, there were more blast furnaces built, and at work, in July 1872, than there were in 1871; and yet pig iron rose unexpectedly to us, just as the coal had done to the coalowners. I believe there

was not a single house in Middlesbro' that had not six months' orders on hand at 45s. to 47s. a ton, when pig iron was selling at nearly 120s.; but as it was up to 120s., they were too glad to give even 41s. a ton for the coke, in order to profit by the increase in the price of iron." In the ordinary course of trade, the fluctuation in the price of coal might have been limited to the particular quality used specially in the manufacture of iron. The demand, however, was apparently so urgent, that it soon extended itself to other qualities, and exercised an influence over their price. The prosperous state of several branches of industry produced a competition for coal which obliged all classes to pay the high price demanded, rather than suffer the loss consequent upon a diminution of business, or the discomfort arising from want of coal for domestic use. The production and export of iron, and the production and consumption of coal, shown in the tables above quoted, might not be deemed sufficient to account for the great rise in the prices of those commodities, but the exact effect of any disturbance of the relations of demand and supply on prices is beyond the limit of arithmetical calculation. Price depends not merely on the quantity of the commodity, but on the motives which influence both the buyer and the seller in determining how much the one is content to receive, and how much the other is willing and able to pay, under the belief that the quantity brought to market is or may be insufficient to meet the demand. In the case of coal, much of the demand is of such an urgent nature, that the buyer would pay a very large price rather than be deprived of the supply he requires. Nor does the ratio of increase of price necessarily bear any definite proportion to the ratio of diminution of supply. A comparatively small deficiency may produce a very large increase of price if the eagerness of each buyer to secure his own supply, and to guard against the deficiency in his own case, is coupled with the ability to pay for it whatever is demanded by the seller. This appears to have been the result of the comparatively small derangement in the production and consumption of coal, enhancing its price in so great a degree. In London, as the largest example of the effect of the disturbance in the coal trade for domestic purposes, it appears from the evidence of an extensive coal merchant that the average prices at the present time, compared with

preceding years, for the best house coal, taken as a standard, are as follows:—

	s.	d.
1868	18	7
1869	18	8
1870	18	6
1871	19	3
1872	24	11
1873, for five months	32	6

The Committee further said they saw no reason to believe that any effort had been made by the colliery proprietors to restrict the supply of coal, for the purpose of creating a scarcity in the market; on the contrary, means had been taken to meet the extra demand. They regretted, however, that some efforts had been made among the workmen to induce them to take active means to prevent the colliery owners from increasing the output of coal, so that high wages might be maintained. The Committee did not consider that any combination either of employers or workmen could by artificial means succeed in permanently altering the laws of supply and demand. The levying of an extra export duty was deprecated. In concluding, the Committee said that it was clearly shown that the real order of events had been the rise in the price of iron, the rise in the price of coal, and then the rise in the rate of wages.

THE COAL SINKINGS IN BRORA.—At the last annual meeting of the South Midland Institute of Engineers, the subject of the borings for coal on the estate of the Duke of Sutherland, at Brora, in Sutherlandshire, was referred to. It was stated that these sinkings had been made in an altogether virgin tract, at the extreme North of Scotland, and at a depth of 80 yards, the men came upon 3 feet 8 inches of coal and 7 feet of oil shale. The sinkings had been conducted to a depth of 90 yards, and they were all through, not the carboniferous, but the oolite formation.

CRAMPTON'S COAL DUST FURNACE.—Mr. Crampton, who read a paper on the subject of this furnace at the last annual meeting of the Institute, has had for some time past an experimental apparatus at work at the Royal Gun Factories, Woolwich, and the working of this in the puddling of iron has proved successful. The *Times* said of the machine :—"It will doubtless prove the forerunner of many more applications in the same direction, and

there appears to be no reason why this system of burning coal dust should not, in course of time, be adopted in other directions where the production of high and even temperatures in an economical manner without smoke is a desideratum."

THE SCOTCH MALLEABLE IRON TRADE.—Before the Cleveland Institution of Engineers, at Middlesbrough, Mr. J. S. Jeans, of Darlington, read a paper, bearing this title. In it, he remarked, that the manufacture of malleable iron was first commenced at Carron, in 1760, and the total quantity turned out in Scotland, during the first 28 years, did not exceed 1,500 tons. There were five blast-furnaces at Carron, in 1792. The Clyde Iron Works next undertook the manufacture of bar iron, and obtained its iron chiefly from Russia and Sweden. The average cost per ton, including cost of freight, was £17 for Russian, and £18 10s. for Swedish iron. Mr. Jeans noticed the various patent appliances which have of late years been tried to lessen the labour of puddling.

THE NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.—Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S., &c., on being elected President, at the annual meeting last year, delivered an inaugural address, in which he considered very fully the economic consumption of fuel. He said the consumption of coal had been increasing each year, at about 4 per cent., and at this rate it could not possibly last. If nothing else was destined to arrest it, the failure of mining labour would inevitably do so. The men used to work nine hours per day, but now they only were six hours in the pit, and they did not work above ten days per fortnight. These two conditions of restricted labour and increasing consumption had caused the demand to overtake the supply; coal was scarce and prices up to a famine pitch. He advocated very strongly that coalowners should make up for the want of human labour by a more extended use of machine labour. He divided the consumption of coal into three great divisions:—(1) domestic; (2) steam engine; (3) ironmaking and other manufacturing processes. He chiefly treated of the first two heads, and afterwards discussed the question of working coal-mines at depths greatly exceeding those of our deepest mines. He cited various evidence given before the Parliamentary Commission of 1866, and continued:—"It fortunately happens that water is never met with in large quantities at great depths, and it is easy to exclude it from the upper portion of a

deep shaft by the modern process of encasing the shaft with cast-iron segments. Nothing, therefore, is to be feared on the score of excessive pumping power being required; neither would there be any practical difficulty in drawing coals from the utmost depth to which we should have to descend. Steel wire ropes, tapering in thickness towards the downward end, would not be overstrained by their own weight added to the usual load, and even if the depth were carried to such an extreme as to render the strain on the rope due to its weight a serious difficulty, the alternative of drawing at two stages could be adopted. With regard to explosive gas, it might have been anticipated that the greater superincumbent weight upon deep coal would cause more gas to exude, and thereby render the workings more fiery, but this does not appear to be the case. On the contrary, the evidence given before the Coal Committee on this point was to the effect that the evolution of gas appeared generally to diminish with increase of depth. In short, the only cause which it is necessary to consider, as limiting the practicable depth of working, is the increase of temperature, which accompanies increase of depth. The rate of this increase of temperature is about one degree Fahrenheit for every 60 feet in depth, starting from 50 feet from the surface, where the temperature is in this country 50 degrees at all seasons. The questions involved in this increase of temperature are:—At what depth would the air become so heated to be incompatible with human labour? And what means could be adopted to reduce the temperature of the air in contact with the heated strata? A great deal of interesting evidence was heard by the Commission as to the limit of human endurance of high temperature. The natural temperature of the human body, or rather of the blood which circulates through it, is 98 degrees. A higher temperature is the condition of fever, and the maximum of fever-heat appears to be about 105 degs. Labour appears to be impossible, except for very short intervals, when the external conditions are such as to increase materially the normal temperature of the blood. The temperature of the air may be considerably in excess of 98 degs., without unduly heating the blood, provided the air be very dry, because the rapid evaporation which then takes place from the body keeps down the internal temperature; but if the air be humid, this counteraction does not take place, or not in a sufficient degree, and then the

blood absorbs heat from the surrounding medium, and the condition of fever sets in. Now, in a coal-mine, the air is never very dry, and is often very moist, and we must, therefore, regard a temperature of 98 degs. in a coal-mine as the extreme limit that could be endured by men performing the work of miners. For my part, I believe this temperature is beyond the limit of possible continuous labour in a mine, and most persons familiar with the interior of coal-mines will agree with me in thinking that even 90 degs. would prove a very distressing temperature, and one which would render the cost of labour much greater than usual. However, granting the practicability of working in a coal-mine in an atmosphere at 98 degs., the next question is—What depth would involve that temperature of the air ? The depth at which the earth would exhibit a temperature of 98 degs. would be about 3,000 feet, but it is a different question at what depth the air circulating through the mine would acquire that temperature. The air being cold when it enters the workings at the bottom of the shaft, absorbs heat with great avidity from the surfaces of the passages through which it flows. As it travels along, it continues to absorb heat, but less rapidly as its own temperature increases. The rate of absorption is complicated by the superficial cooling of the passages by the contact of the air. This cooling action is necessarily greatest near the shaft, where the air is coldest, and diminishes by increase of distance, so that both the air, and the surfaces against which it sweeps, become hotter as the length of the air-course is increased. The progress towards complete assimilation of temperature is much slower in the permanent air-courses than at the working face of the coal, because the coal, at the face, being newly exposed, is hotter, and, therefore, communicates heat more readily to the air. In any case, however, the air will eventually acquire the full heat due to the depth, if its contact with the strata be sufficiently prolonged. It follows, therefore, that the temperature of the air in a mine depends on the extent of the workings, as well as on the depth of the pit. But great depth involves extensive workings, because the cost of the sinking could only be repaid by working a large area of coal. Extremely deep mines will consequently possess both the conditions tending to produce a high temperature of the air, and unless those conditions can be counteracted by some artificial expedient, the air would acquire

the temperature of 98 degs., assumed to be the limit of practicable labour, at a depth not greatly exceeding 3,000 feet. It is a common idea that increase of temperature may be kept down to any extent by increase of ventilation, but this opinion will not bear examination. In the first place, it requires an extravagant increase of motive power to accelerate the velocity of the current of air in any considerable degree, because the resistance increases in a ratio somewhat exceeding the cube of the velocity. In fact, the only way of materially increasing the volume of air is by enlarging the sectional area of the shafts and air-courses, which would be attended both with difficulty and expense. Sir William closes his address as follows:—"The conclusion to which the Committee came, as to the depth at which coal could be worked, is expressed in the following words:—'The depth at which the temperature of the earth would amount to 98 degs. would be about 3,000 ft. Under the long-wall system of working, a difference of about 7 degs. appears to exist between the temperature of the air and of the strata at the working faces; and this difference represents a further depth of 420 ft., so that the depth at which the temperature of the air would, under present conditions, become equal to the heat of the blood would be about 3,420 ft. Beyond this point the considerations affecting increase of depth become so speculative, that the Committee must leave the question in uncertainty; but they consider that it may be fairly assumed that a depth of at least 4,000 ft. could be reached.' The Committee declined to deal with hypothetical expedients for overcoming the difficulties, but they recognised the possibility of future discovery and experience counteracting, in some unknown degree, the effects of heat and humidity in restricting the depth of working. It will, therefore, be for mining and mechanical engineers to bring all the resources of their science to bear upon this difficult problem of counteracting terrestrial heat, at depths where it approaches the limit of human endurance. The Commissioners adopting 4,000 ft. as the probable limit of practicable depth, came to the conclusion that there exists in this kingdom an aggregate quantity of about 146,480 millions of tons of available coal. If we assume that the future population of this country will remain constant, and that the consumption for domestic and manufacturing purposes, including exportation, will continue uniform at the present quantity, or merely vary from year to year

without advancing, then our stock of coal would represent a consumption of 1,273 years. But, if, on the other hand, we assume that population and consumption will go on increasing at the rate exhibited by the statistics of the last fifteen years, or, I might probably say, of the last fifty years, had accurate statistics been so long recorded, then the whole quantity of coal would, as shown by Mr. Jevons, be exhausted in the short space of 110 years. It will be generally admitted that the truth is likely to lie between these two extremes. The Commissioners refrained from expressing an opinion as to what the period of duration would actually be, but they presented certain alternative views of the question, resulting in periods varying from 276 to 360 years. But all these estimates of duration have reference to the time required for absolute exhaustion of available coal, and leave untouched the important question of how long we are likely to go on before we become a coal-importing instead of a coal-exporting country. The computation of quantities made by the Commissioners includes all coal seams exceeding one foot in thickness, whatever the quality may be, and it is obvious that vast quantities of such coal can never be worked, except at a price which would render it more advantageous to purchase coal from abroad than to work it from such unfavourable beds. If, at the present time, while working our best and most available coal, our markets will barely exclude the coal of Belgium, what will be our position when driven to inferior coal more costly to work? If we look to cheaper labour for enabling us to work less valuable coal, I fear we shall look in vain; but there is one hope for a longer endurance of our prosperity as dependent on our coal, and that hope rests on the skill and perseverance of mining and mechanical engineers, who, even now, are called upon to lessen, by all the resources of mechanical science, the amount of human labour required in coal mines."

Surface Drainage of the South Staffordshire Coal-field.—At the annual meeting of the South Staffordshire and East Worcestershire Institute of Mining Engineers, Mr. E. B. Marten read a short paper on this subject. It had long been known, he said, that the difficulty of clearing mines from water was much increased by an undue quantity passing through the disturbed surface, and also, that the water pumped in one colliery got into others not far distant, and had to be pumped up again.

He had made an attempt, in 1865, to ascertain the quantity of water raised from the mines in South Staffordshire, and also the rainfall of the district, and the outflow by rivers, streams, and canals, and the result was sufficiently accurate to show that the daily quantity of 50,000,000 gallons, pumped from the mines, could only be accounted for on the supposition that a large proportion of the water found its way back to the mines, to be re-pumped. He spoke much in favour of the South Staffordshire Mines Bill, which has since become law, which he said would remedy the evils from which the district suffered. Messrs. Henry Johnson and D. Peacock afterwards read a paper on the same subject, also in favour of the Bill.

The Experience Afforded in the Manufacture of Coke During the last Twelve Years.—Mr. A. L. Steavenson read a paper bearing the above-named title to a meeting of the North of England Institute of Engineers. He stated that the rapidly increasing cost of coke had to a great extent reduced the quantity used for locomotive purposes, and had compelled the ironmaster to economise in the use of it, and every effort should be made to prevent waste in its production. The writer divided his subject into three heads: 1st. The utilization of the constituents of the gases; 2nd. The preliminary treatment of coal, both chemical and mechanical; 3rd. The heat afforded, utilized, or lost. Under the first head he said that in the old oven, the round or bee-hive shape, was the best under general circumstances. He described some ovens built by Messrs. Bell Brothers, which produced 68 per cent. of coke, but the system was not a success, owing to the inferior quality of the produce and the great cost of maintainence. Some ovens built by the Wigan Coal and Iron Company were referred to, especially to one being tried there by Mr. Homfray, which was said to be a success. In the Appolt system, he considered the weak point lay in the non-evaporation of the water, the coke having to be watered externally, and an excess of moisture was the result. In the "Brecken and Dixon" oven, what was gained in percentage of coke was lost in quality. The Belgian oven tried in the district he did not think was a success.

Gases Occluded by Coal.—Professor Marreco read a condensed abstract of an account of Dr. Ernst von Meyer's recent examination on this subject, before the same Institute. Dr. Meyer had taken

both German and English coal, and they appeared to differ considerably. German coal occluded in a very condensed condition more than one-half of its volume of mixed gases; the occluded gases containing marsh gas, carbonic acid, nitrogen, and a little oxygen. There was great variation in the English coal, some of the five-quarter containing the merest trace of marsh gas, and some as much as 86 per cent.

Coppee's Coke Ovens.—Mr. Emerson Bainbridge read a paper on this subject, before the Institute of Mining Engineers, at Newcastle-upon-Tyne. The points to be considered in producing a good coke were, he said: (1) freedom from sulphur; (2) freedom from ash; (3) cohesive strength to resist a crushing strain. The chief purposes for which coke was used in England were: (1) the smelting of iron in blast-furnaces; (2) foundry purposes; (3) Bessemer steel melting; (4) crucible steel melting. In the first three processes, the coke should be hard, dense, and free from sulphur. The class of ovens generally used in England were known as the "Bee-hive," and they produced, on an average, when bituminous coal was used, washed, 47 per cent., and unwashed, 57 per cent., while they turned out a ton per day. The coking process took from 48 to 120 hours, and the ordinary cost per oven was £45. He then compared this oven with the Coppée, a full description of which will be found in M. Gillon's communication, in another part of the Journal.

Coke Ovens.—At the meeting, held on February 24th, 1874, of the Institution of Engineers and Shipbuilders, in Scotland, Mr. William Clapperton read a paper on the subject of coke ovens, which was chiefly a comparison between the Appolt and Coppée ovens and our own Bee-hive ovens.

Disintegration and Utilization of Slag.—At the December meeting of the Cleveland Institution of Engineers, Mr. Charles Wood, of the Tees Iron Works, Middlesbrough, read a paper on this subject. He gave a history of the various attempts made for the purpose of utilizing blast-furnace slag, 30 of which were patented, and 12 or 14 others not patented. The first attempt was to use it for road making, for which purpose it was simply broken by hand, and used like other stone, but this plan did not succeed, the material being too soft and brittle. The author noticed a plan of M. Sepulcre's, which made good

paving blocks, but better building stone. The next plan treated of was to run it in its molten state into moulds, in the shape of bricks, tiles, &c. Mr. Manby, in 1873, tried this plan. Mr. Wood's opinion, after examining the question thoroughly, was that slag bricks made by casting were never likely to supersede red bricks, or to come into commercial use. In 1848, a gentleman offered a premium of 50 guineas for the best series of experimental researches on, and specimens of, the application of slag, or other allied products, to any new purpose, useful or ornamental, but no one ever claimed the 50 guineas. In 1854, Dr. Smith, of Philadelphia, and Mr. Henry Bessemer, took out a patent for dealing with slag by casting it into objects of art, &c., and a company, with a capital of £120,000, was formed to carry out the system. One plan which they proposed, was to cast the slag into hot sand moulds and to remove the castings with the sand upon them into an annealing oven, after which they were cleaned and the surface polished. Though some good specimens were made in this way, and though neither energy nor ability were wanting, this scheme did not succeed on account of the difficulty of overcoming the contraction of the material. Another plan attempted was to blow the liquid slag by means of jets of air or steam. In Silesia, operations on it in this manner were successful, and many uses were found for the material. The liquid slag was blown upon above or underneath the stream with a heavy pressure of blast or steam. It was thus drawn out into a mass of fine threads of a similar substance to that produced by spinning glass, and as it had the appearance of dirty foreign wool, it was called furnace or mineral wool. It had been proposed to use this as a non-conductor for boilers and steam pipes, but the quantity of air and steam required, and the difficulty in collecting this substance when blown out, rendered the production of it a difficult matter. Thus the numerous schemes for conversion of the liquid slag into useful articles, had been attended with various causes of non-success. By the manipulations of this material in a granulated form, it could be chemically reunited, moulded into any form or shape, and allowed to harden by exposure to the air; and by this, all the most valuable properties (which by the direct system lay latent and useless) could be brought into action. The employment of ground slag in place of sand in mortar and cement had been practised with varied success for 23 years, and several

patents had been taken out during that time for artificial stone, concrete bricks, blocks, mortar, cement, &c., and the commercial non-success of these had been owing, not to the quantity of the material produced, but to the mechanical difficulty of reducing the slag to powder. Mr. Crossley, had given the following analysis of grey slag:—

Silica	38·25	per cent.
Alumina	22·19	„
Lime	31·56	„
Magnesia	4·14	„
Protoxide of Iron	1·09	„
Manganese	Trace	
Calcic Sulphide	2·95	„
	100·18	„

In silica, alumina, and lime, there were the three most important ingredients of cements and mortars; in calcic sulphides those of plaster of paris. Adding quick lime to these in a finely sub-divided state, a chemical action set in, dissolving and liberating in the first instance each ingredient, and then re-uniting and hardening the whole into a cement like-substance. This would show the valuable chemical ingredients of the material, but the cost of reducing it to powder being so heavy, and its inferior substitute—sand—being in the market at such a low rate had effectually excluded it from use. To crush slag into dust or sand, cost at least 6s. per ton, whilst common sand could be purchased at from 1s. 6d. to 2s. Various methods had been introduced to produce fine slag at cheaper rates; amongst others that employed by Mr. Gjers, in 1862. The liquid slag was run upon plates or into shallow water; this produced a frothy mass, which was broken up by hand and then ground in a mortar mill. It was employed successfully upon the pig beds. The sand, however, when used for some time, consolidated, and during wet weather caused boils from the non-absorption of the rain, and in consequence had to be given up. This might be obviated in a great measure by the beds being covered in, as on the Continent. If, however, this slag could be produced at one-half the cost of ordinary sand, these chemical ingredients would have their full sway, and cement, concrete, artificial stone, and many other

things, could come into the market to the exclusion of that hitherto indispensable and invaluable opponent—building sand. The first successful machines for producing granulated slag were those now in use on the Continent, but, however well these might work abroad, on account of the different quality of the produce, they would be quite unadaptable to Cleveland. The first machine set to work in England was that of Mr. Bell, of Newcastle, then the author's revolving table, and lastly Mr. Joy's. Mr. Wood then proceeded to describe the two machines invented by himself, which he considered the only machines that had worked satisfactorily. By the second of these, slag sand could be made at the cost of only 5d. per ton. Mr. Wood showed specimens of mortar composed of 1 part lime and 6 parts slag sand, which could, he said, be made at the rate of 4s. 6d. per ton of finished mortar, whilst the commonest class of mortars employed by builders were not less than 16s. per ton. If to this, one part of calcined ironstone or spent pyrites were added, a most valuable cement was produced, which got harder with age. A piece of cement made in this way was tested by placing it in water, when it only absorbed 0·90 per cent. Concrete walls, foundations, and blocks were made by taking the slag from the author's first machine, and working it up with the slag cement in the same way as the French made Béton, at the rate of about 3s. 6d. per ton. This he considered stronger than ordinary brick work, which would cost about six times as much, and was almost impervious to wet. The author also stated that 12,000 tons of this concrete had been made during the past year, and many fine houses were built of it. A company had been formed—the Cleveland Slag Working Company—for manufacturing the concrete bricks from this sand, which bricks would cost but 12s. per thousand. The machinery used was Captain Bodmer's patent. Mr. Wood dwelt at great length on the value of slag as a manure, as it contained about 32 per cent. of lime, 40 per cent. of silica, and 3 per cent. of sulphate of lime or calcic sulphide. It would tend to open up and lighten the land. He combatted the remarks of Mr. I. Lowthian Bell on this subject, and showed, from actual application, that this slag was a cheap substitute for lime. There was undoubted proof that many lands were completely exhausted by the constant extraction of the silica by the straw. He quoted the opinions of various agriculturists as to the benefit derived from the use of crushed slag as a fertilizer.

In the discussion which followed, Mr. David Joy described his plan of disintegrating slag, and other speakers referred very pointedly to the efforts that had been made from time to time in Belgium to utilise slag. A method employed by M. Sepulcre, at Nancy, was especially noticed, as was also another for blowing the slag into wool at the Georgmarienhutte furnaces in Hanover.

PRODUCTION OF PIG IRON IN CLEVELAND.—The following are the figures which have been officially published from time to time by the Cleveland Ironmasters' Association. They relate to the output of pig iron in the North-Eastern district of England during the years 1871, 1872, and 1873:—

	1871. Tons.	1872. Tons.	1873. Tons.
January	151,826	160,567	164,125
February	141,068	155,672	154,491
March	161,049	168,685	172,539
April	155,472	163,408	165,007
May	164,082	168,795	158,235
June	155,912	162,207	163,829
July	158,126	162,603	166,441
August	157,053	162,808	168,027
September	152,857	161,028	167,078
October	163,027	171,316	173,123
November	160,307	165,822	170,512
December	163,460	166,061	176,084
	1,884,239	1,968,972	1,999,491

At the end of December, 1873, there were 139 furnaces erected, and of these 132 were in blast, as compared with 137 erected and 130 at work at December 31st, 1872, and 131 built with 124 in operation at December 31st, 1871. Twenty-one blast furnaces were in course of construction in December, 1873. The stock of pig iron held by the various makers on December 31st, 1873, was 80,328 tons as compared with 40,697 tons at the same time in 1872.

THE SCOTCH IRON TRADE.—The following statistics have been published relative to the production, shipment, and stock of Scotch pig iron during the last 25 years. The number of furnaces built and in operation at the end of each year is also given:—

Pig Iron at Dec. 31.	Furnaces Erected.	In Blast.	Production. Tons.	Shipments. Tons.	Estimated Stock. Tons.
1849	143	113	692,000	374,431	194,000
1850	143	105	630,000	324,658	275,000
1851	143	114	775,000	450,000	350,000
1852	144	113	780,000	424,000	450,000
1853	144	114	720,000	620,000	220,000
1854	149	115	780,000	590,000	130,000
1855	157	122	820,000	542,000	110,000
1856	161	128	820,000	500,000	100,000
1857	165	125	900,000	532,000	168,000
1858	165	134	950,000	560,000	330,000
1859	170	125	980,000	575,000	390,000
1860	171	133	1,000,000	576,000	500,000
1861	171	122	1,040,000	590,000	600,000
1862	170	125	1,080,000	565,000	700,000
1863	171	134	1,150,000	620,000	720,000
1864	163	135	1,160,000	676,000	760,000
1865	163	136	1,164,000	740,500	652,000
1866	164	98	994,000	636,500	510,000
1867	164	112	1,031,000	647,738	473,000
1868	162	121	1,068,000	585,200	568,000
1869	159	130	1,150,000	651,000	620,000
1870	160	126	1,206,000	655,000	665,000
1871	154	126	1,160,000	870,000	490,000
1872	154	115	1,090,000	916,000	194,000
1873	152	122	993,000	694,000	120,000

ESTIMATION OF MANGANESE IN SPIEGELEISEN.—Mr. John Parry, of Ebbw Vale Iron Works, South Wales, has furnished a paper, on the above-named subject, to the *Chemical News*, of which the following is an abstract:—The ordinary method of separating MnO from Fe_2O_3 is by precipitating the latter with ammonia and sodic acetate, retaining MnO in solution, to be estimated by precipitation with bromine and

ammonia. Manganese may thus be very accurately estimated, yet it is difficult to ensure the perfect separation of MnO from Fe_2O_3; the presence of the latter in solution is easily detected, but it is well known that it is not easy to obtain the Fe_2O_3 precipitate free from traces of manganese, and it is necessary to re-dissolve the Fe_2O_3 precipitate, and boil afresh with sodium acetate; in most instances, a further notable quantity of manganese is found. On the whole, the process is a very slow one, requiring more time and attention than can well be spared in a busy laboratory where frequent and rapid manganese estimations are called for. It occurred to the author that Fresenius and Will's method—in which the quantity of MnO_2 in manganese ore is determined by the amount of CO_2 evolved on treatment of the ore with sulphuric acid and sodium oxalate—might be applied to the estimation of manganese in spiegeleisen, provided the latter could be obtained in the form of a dry oxidized product, containing always a definite manganese oxide, either MnO_2 or Mn_2O_3. After many trials, the following process was found to give good results. 0·5 grm. spiegeleisen dissolved in nitric acid (sp. gr., 1·2), and evaporated to dryness in a small pear-shaped glass flask, and, lastly, heated to redness over a small Bunsen's burner for ten minutes, the flask and its contents allowed to become quite cold, sodium oxalate and hydrochloric acid added, and the flask, &c., quickly connected with the apparatus for collecting and measuring the CO_2 evolved;* the glass cylinder and graduated tube having been previously filled with mercury, by pouring mercury into the cylinder, thence rising in the graduated tube, which is open at the bottom. The flask is gently heated until a clear solution is obtained, and the CO_2 generated passes into the tube. As the gas passes into this tube, the top of the syphon is opened, and the mercury run out into a receiver. The mercury in the tube and cylinder must be kept at about the same height, otherwise the india-rubber cork closing the flask may be blown out. When sufficiently cool, the flask is plunged into water, and allowed to remain there not less than ten minutes, until the water has attained the same temperature as that in glass cylinder enclosing the gas-tube. Mercury is poured into the cylinder until the mercury in the tube and cylinder stands at the same height, the number of divisions of CO_2 evolved read off noting the

* A small chloride of calcium tube is attached here.

temperature of the water in the cylinder and receiver, also the height of the barometer. The gas-tube used by the author is graduated in m.m.—the upper smaller part, about 300 m.m.=30 c.c. capacity, the wide lower part, about 150 m.m.=50 c.c. capacity. These are only approximate. Of course, each tube must be carefully calibrated previous to use, and the value of each division determined. The number of c.c. CO_2 (B., 760; T., 0°) being known, it is easy to calculate the corresponding quantity of manganese—87 parts by weight MnO_2=88, CO_2=55 manganese. It was, however, found impossible to obtain a product containing MnO_2. Although many experiments were made with this object, heated over the Bunsen's burner as previously described, the manganese was always present as Mn_2O_3, and further heating for thirty minutes showed no loss of oxygen. Consequently, 88 parts CO_2 represented 110 metallic manganese. Example:—

0·5 grm. spiegeleisen gave CO_2	31·80 c.c.
Temperature	19·00°
Barometer	738·00 m.m.
Tension of aqueous vapour	16·36 „

$$\frac{31{\cdot}8 \times 721{\cdot}64}{760 \times (1) + (0{\cdot}003665 \times 19)} = \frac{28{\cdot}22 \text{ c.c. } CO_2 \times 0{\cdot}1966 \times 110}{88} =$$

$$= 0{\cdot}06934 \text{ grm. Mn.}$$

Manganese ... ... 13·868 per cent.

The above calculations appear rather tedious, but it is evident the calculation takes less time than when manganese is estimated by precipitation, the latter process requiring at least six hours, and in most instances a much longer time. Also the calculation may be simplified by the use of the tables given in Sutton's "Volumetric Analysis," where the divisor for the formula—

$$\frac{V \times B}{760 \times (1 \times \delta T)}$$

is given. Also the value of 1 c.c. of CO_2 shown by the instrument may be expressed in parts by weight of Mn. Thus, 28·22 c.c. CO_2 =0·06934 grm. CO_2; therefore, 1 c.c.=0·00245716 grm. Mn, which, multiplied by x c.c. CO_2 found, gives at once the corresponding amount of manganese.

Test Experiments—

0·500 grm.	spiegeleisen		gave	28·20	c.c. CO_2	=13·860	%	Mn
„	„		„	28·05	„	=13·800		„
By weight—Manganese	...	...	...	...		13·740	%	
0·500 grm.	spiegeleisen	(1)	gave	23·57	c.c CO_2	=11·600	%	Mn
„	„	(2)	„	„	„	„		„
„	„	(3)	„	„	„	„		„
„	„	(4)	„	„	„	„		„
„	„	(5)	„	„	„	„		„
0·253 „	„		„	11·70	„	11·500		„
0·264 „	„		„	12·60	„	11·350		„
0·250 „	„		„	11·80	„	11·590		„
1·000 „	„		„	47·00	„	11·547		„
By weight	...	...	...	...	...	11·530		„

By substituting water for mercury, and connecting the tube with a bladder, &c., immersed in a large beaker of water (see Fresenius's "Analysis." 5th ed., p. 152), results sufficiently accurate have been obtained, and the trouble and expense of the use of mercury obviated. The apparatus becomes a modification of Schiebler's, and may be used for the same purpose, also applied to the determination of CO_2 in limestone, ores, &c. The above method of analysis only occurred to the author after a perusal of a paper written by Dr. Russell on the measurement of gases as a branch of volumetric analysis; previously, attempts were made according to Bunsen's method, in which the chlorine resulting from the decomposition of MnO_2 or Mn_2O_3 by HCl is passed into iodide of potassium solution, and the liberated iodine titrated with hyposulphite of sodium; this method, however, did not give good results. This method has been applied to the determination of manganese in steel, treating not less than 4 grms. steel, and measuring over mercury. The dry product requires a rather stronger heat, best accomplished by heating over a small Bunsen's burner in an open platinum capsule. It is best to take 10 grms. steel, and evaporate to dryness in a porcelain dish, and heat a weighed portion of the dry residue as above, reserving part for a second trial.

THE BOARD ON TRADE RETURNS.—The following figures give the exports of IRON, STEEL, COAL, and COKE from the United Kingdom during the years 1871, 1872, and 1873:—

IRON.

		1871. Tons.	1872. Tons.	1873. Tons.
PIG	To Germany	203,284	310,597	261,642
	,, Holland	246,092	352,895	330,398
	,, France	71,265	90,234	89,156
	,, United States	190,183	195,151	102,624
	,, Other Countries	346,634	382,266	355,844
	Total	1,057,458	1,331,143	1,139,664
BAR, ANGLE, BOLT, AND ROD	To Germany	15,007	17,799	26,850
	,, Holland	8,376	8,479	13,320
	,, France	766	1,331	2,494
	,, Italy	33,040	19,557	25,067
	,, Turkey	11,176	7,027	8,471
	,, United States	64,301	64,583	23,006
	,, British North America	45,146	46,536	31,339
	,, ,, India	27,472	16,054	22,578
	,, Australia	12,393	20,841	15,571
	,, Other Countries	131,407	111,393	119,726
	Total	349,084	313,600	288,422
RAILROAD OF ALL SORTS	To Russia	78,367	106,939	162.275
	,, Sweden and Norway	12,590	13,172	50,172
	,, Germany	50,287	50,105	41,984
	,, Holland	14,868	5,125	20,599
	,, France	2,653	2,117	2,497
	,, Spain and Canaries	13,199	12,274	13,590
	,, Austrian Territories	24,260	7,989	816
	,, Egypt	16,759	14,484	13,951
	,, United States	512,277	467,304	185,702
	,, Spanish West India Islands	3,848	3,330	4,446
	,, Brazil	20,519	20,743	15,047
	,, Peru	29,262	36,613	8,462
	,, Chili	11,130	2,553	5,852
	,, British North America	61,961	77,255	54,573
	,, ,, India	34,523	14,651	18,087
	,, Australia	14,691	25,094	35,089
	,, Other Countries	80,003	85,672	153,658
	Total	981,197	945,420	786,800
WIRE OF IRON OR STEEL (except Telegraph Wire), galvanised or not		26,200	33,540	29,884
HOOPS, SHEETS, AND BOILER & ARMOUR PLATES	To Russia	17,334	12,344	17,965
	,, Germany	14,406	16,034	26,023
	,, Holland	8,570	9,810	11,759
	,, France	2,008	3.162	4,818
	,, Spain and Canaries	5,145	6,207	5,139
	,, United States	41,520	31,407	18,291
	,, British North America	16,229	16,043	9,447
	,, ,, India	15,871	18,055	16,770
	,, Australia	13,928	20,267	21,360
	,, Other Countries	65,326	74,166	69,865
	Total	200,337	207,495	201,437

		1871. Tons.	1872. Tons.	1873. Tons.
TIN PLATES	To France	2,123	3,342	3,941
	,, United States	86,929	87,360	85,531
	,, British North America	4,200	4,003	3,343
	,, Australia	5,141	5,094	4,326
	,, Other Countries	21,212	18,284	23,327
	Total	119,605	118,083	120,468
CAST OR WROUGHT, AND ALL OTHER MANUFACTURES (except Ordnance) unenumerated	To Russia	14,608	18,434	42,880
	,, Germany	25,051	28,607	28,183
	,, Holland	12,217	13,598	16,485
	,, France	4,359	4,805	5,054
	,, Spain and Canaries	4,158	5,760	8,849
	,, United States	10,671	13,468	22,279
	,, British North America	16,245	21,599	16,917
	,, ,, Possessions in South Africa	2,380	3,752	4,986
	,, ,, India	29,499	20,283	18,762
	,, Australia	18,694	23,595	31,270
	,, Other Countries	107,416	115,706	86,500
	Total	243,298	269,607	282,165
IRON, OLD, for re-manufacture		139,812	107,521	60,478

STEEL.

		1871.	1872.	1873.
UNWROUGHT	To France	1,764	3,204	2,544
	,, United States	21,133	23,821	19,262
	,, Other Countries	16,292	17,944	17,682
	Total	39,189	44,969	39,488
MANUFACTURES OF STEEL OR STEEL AND IRON COMBINED		13,038	11,384	10,508
TOTAL OF IRON AND STEEL		3,169,219	3,382,762	2,959,314

COAL, COKE, &c.

		1871. Tons.	1872. Tons.	1873. Tons.
COAL, COKE, CINDERS, AND FUEL MANUFACTURED	To Russia	914,432	796,178	613,831
	,, Sweden and Norway	626,707	765,308	788,782
	,, Denmark	658,707	641,508	589,512
	,, Germany	2,396,811	2,113,589	1,674,397
	,, Holland	506,470	471,459	467,147
	,, France	2,006,152	2,191,855	2,475,649
	,, Spain and Canaries	596,952	637,046	613,023
	,, Italy	826,059	928,870	796,930
	,, Brazil	329,307	329,584	395,249
	,, British India	594,229	549,486	540,118
	,, Other Countries	3,292,163	3,773,611	3,677,695
	Total	12,747,989	13,198,494	12,632,333
COAL, &c., shipped for the use of steamers engaged in the foreign trade		(for eight months)		2,208,315

LIST OF DONATIONS.

The following is a list of the publications presented to the Institute since August, 1872:—

Cleveland Institution of Engineers.—Proceedings, November, December, 1872, February, March, April, November and December, 1873, and January and February, 1874.

Mr. David Kirkaldy.—Kirkaldy's Experimental Enquiry into the Mechanical Properties of Fagersta Steel.

Eastern Ironmasters' Association, New York.—Account of Annual Meeting, 1872.

Institution of Civil Engineers.—Excerpts from Minutes; Vernon Harcourt on the New South Dock of the West India Docks; Latham on the Soonkesala Canal of the Madras Irrigation and Canal Company; William Anderson on the Aba-el-Wakf Sugar Factory, Upper Egypt; Colonel Greathed on the Practice and Results of Irrigation in Northern India; John Milroy on the Cylindrical or Columnar Foundations in Concrete, Brickwork, and Stone-work; Gordon on the Value of Water, and its Storage and Distribution in Southern India; Bainbridge on the Kind-Chaudron System of Sinking Shafts through Water-Bearing Strata; Andrews on the Somerset Dock at Malta; Bashley Britten on the Construction of Heavy Artillery; T. Sopwith, junr., on the Mont Cenis Tunnel; Pole on the Rigi Railway; Welsh on the River Witham Drainage; Thornton on the State Railways of India; Deas on the River Clyde; Hartley on the Delta of the Danube; Address of T. E. Harrison, Esq., on his Election as President; Report of Speeches at Annual Dinner, 29th March, 1873; and List of Members, June 1st, 1873.

Institution of Engineers and Shipbuilders in Scotland.—Transactions, October, November, and December, 1873, and January and February, 1874.

Institution of Naval Architects.—Proceedings, Vols. 11 to 14.

Institution of Surveyors.—Transactions, Session 1871-72.

Institution of Mechanical Engineers.—Proceedings, Parts 1 and 2, July and October, 1872, and May, 1873.

Mr. L. D. B. Gordon.—Gruner's studies of Blast Furnace Phenomena, Translated by Mr. Gordon.

Leeds Association of Foremen Engineers.—Proceedings, Session 1871-72.

London Association of Foremen Engineers.—Proceedings, 1873.

London Association of Engineers and Draughtsmen.—Journal, January, 1874.

Manchester Literary and Philosophical Society.—Proceedings, Vol. 13.

North of England Institute of Mining and Mechanical Engineers.—Transactions, Vol. 22, Part 4. February and March, 1872, Vol. 21, Part 2. October and November, 1872, and February, 1873, Vol. 22, Part 1. March and April, 1873, Vol. 21, Part 2. May, June, and August, 1873, Vol. 22, Part 3. December, 1873.

Society of Engineers.—Proceedings, 1868.

South Wales Institute of Engineers.—Proceedings, October, 1872, April, 1873, Vol. 8, Nos. 2 and 3, and December, 1873.

South Staffordshire and East Worcestershire Institute of Mining Engineers.—Proceedings, June to December, 1871.

Mr. C. P. Sandberg.—Safety of Permanent Way, with Drawing and Tables concerning Punching and Notching of Rails, by C. P. Sandberg.

Mr. Hiram Haines.—The State of Alabama, its Mineral, Agricultural, and Manufacturing Prospects, by Hiram Haines, C.E.

The Editors.—The Engineering and Mining Journal, New York.

The Royal Society.—Proceedings, Vol. 20, No. 136, 138; Vol. 21, Nos. 140, 141, 142, 143, 144, 145, 146, 147; Vol. 22, Nos. 148, 149, and 150.

L'Association des Ingenieurs Sortis de L'Ecole de Liege.—Bulletin Trimestriel, No. 1, 1873.

Naval Science.—April, July, October, 1873; January and April, 1874. Lockwood and Co., 7, Stationers' Hall Court, E.C.

Dr. J. W. Foster.—Mineral Wealth and Railway Development, New York, 1872.

Railroad Committee.—2nd Annual Report, Boston, 1871.

National Association of Iron Manufacturers.—Statistical Report for 1872, Philadelphia, 1873.

Chamber de Commerce de Verviers.—Rapport pour 1871, Verviers, 1872.
Do. Do. Liege.—Rapport pour 1872, Liége, 1873.
Do. Do. Anvers.—Rapport pour 1871, Anvers, 1872.
Do. Do. Anvers.—Rapport pour 1872, Anvers, 1873.

Convention of American Pig Iron Manufacturers. — Annual Report, Philadelphia, 1872.

Prof. H. Wedding.—Grundriss der Eisenhuettenkunde, Berlin, 1871.
Do. Do.—Eisenhuettenkunde nach Percy, vols. 1 and 2, Braunschweig, 1864-1873.

Max. Goebel.—Les Charbons Belges en 1869, Liége, 1871.

Prof. S. Jordan.—Notes Sur la Fabrication de l'Acier Bessemer aux Etats Unis, Paris, 1873.

Prof. S. Jordan—Revue de l'Exposition du Fer en 1867, Paris. Vol. 1, Fabrication de la Fonte. Vol. 2, Fabrication du Fer et de l'Acier.

Prof. S Jordan.—Sur la Fabrication des Fontes Specielles, 1869, Paris.

E. Laguesse.—Rapport sur l'Industrie Mineral de la Province de Hainaut, Mons., 1871.

Lewis and Rossiter.—Miscellaneous Rolling Mill Information, No. 6, 7, 8; 1871, 1872-3.

PERIODICALS.

ZEITSCHRIFT F. D. BERG-HUTTEN-U. SALINEN-WESEN. I. D. PREUSSISCHEN STAATE.—Berlin, 1867-1874.

ANNALES DU COMMERCE EXTERIEUR.—Paris, 1872-1874.

LA MINERIA.—Madrid, 1872-1874.

REVISTA MINERA.—Madrid, 1872-1874.

MONITEUR DES INTERETS MATERIELS.—Brussels, 1872-4.

CHRONIQUE DE L'INDUSTRIE.—Brussels, 1872-3.

AMERICAN MANUFACTURER.—Pittsburg, 1873-4.

REVUE INDUSTRIELLE.—Paris, 1874.

BULLETIN DE L'UNION DES CHARBONNAGES MINES, &c, DE LA PROVINCE DE LIEGE.—Liége, 1872-74.

AMERICAN JOURNAL OF SCIENCE AND ARTS.—Newhaven, 1872-4.

REVUE UNIVERSELLE DES MINES ET METALLURGIE.—Liége, 1872-4.

Iron and Steel Institute, London
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